PROCEEDINGS

OF THE

National Annual Meeting

FOREST PRODUCTS RESEARCH SOCIETY

Research · Development · Production · Utilization

MULTNOMAH HOTEL

PORTLAND, OREGON

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MONDAY, TUESDAY, WEDNESDAY AND THURSDAY

JUNE 26, 27, 28 and 29

1950

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VOLUME FOUR

FOREST PRODUCTS RESEARCH SOCIETY
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FOREST PRODUCTS RESEARCH SOCIETY

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1950 NATIONAL ANNUAL MEETING

The Technical Sessions of the 1950 Annual Meeting were held in the Assembly Room of the Multnomah Hotel in Portland, Oregon with the exception of Sessions III and IV, which were held in the Junior Ballroom. The Forest Products Industry Show was held in the Portland Armory. Session I was opened by President Locke at 9:00 A. M., Monday, June 26.

Registration

Registration was opened at 4:00 p. m., Sunday, June 25, in the Studio Room, to all interested persons, whether members or nonmembers. A registration fee of $5.00 included preprints of papers. During the four days a total of 515 persons were registered. Admission to the Forest Products Industry Show was by invitation, and 846 persons registered at the Armory between Monday morning and Wednesday evening. The meeting, while largely attended by West Coast people, drew representatives from 34 states, Canada, and many foreign countries, including New Zealand, Scotland, England, Germany, France, Mexico and South Africa.

General Assembly Luncheon

President Locke extended official welcome to the registrants and their wives at the General Assembly Luncheon Monday, in the Rose Bowl of the Multnomah Hotel. Governor McKay of Oregon and Mayor Lee of Portland, who were personally unable to be present, also sent official greetings through their emissaries, Senator Walsh and Commissioner Cooper. President Locke expressed the Society's appreciation to General Chairman R. D. Pauley and the members of the 1950 National Annual Meeting Committees for their excellent program and arrangements.

Robert T. Dwyer, Vice President of the Dwyer Lumber Company, Portland, gave the keynote luncheon address, *"Use of Our Timber Resources."* In describing the industry's significant strides toward better utilization, he cautioned also of our wastes. He related how, in preparing for an address before the Industrial College of the Armed Forces on logging and lumber problems of the Douglas Fir region, he wrote 50 letters to people in the region.

The answers he received were so complete and patriotic that he presented them as a brief. One of their outstanding similarities was the thought that in the event of crisis we would need access roads built into public forests, *in advance,* to avoid competition for men and equipment.

Construction of such roads now, he said, would allow practice of good sustained yield forestry, remove windfalls and decadent stands . . . and protect forests from their greatest enemy—fire.

With proper management the forest lands of the country will supply our needs for all time to come. And the Forest Products Research Society, a society of research and forest products men, is on the road toward this goal.

Field Trips

Tours of inspection through some of the world's largest wood products plants around Portland were held all day Thursday, June 29. A highlight was the sixty-mile round trip taken by some 100 persons to Longview, Washington, "The Forest Products Capitol of the World", named so after mills made famous by Weyerhaeuser, Longview Fibre and Long–Bell.

President's Reception

An informal reception held at the new Cosmopolitan Club on Wednesday evening was attended by some 300 guests. A buffet supper was followed by entertainment and dancing.

Mt. Hood—Timberline Lodge

The social highpoint of the meeting was the scenic bus journey taken up Mt. Hood on Tuesday afternoon. Many rode the world-famous mile-long chair lift to a point 1,000 feet further up the slope where they could get a better view of the spectacular seven major peaks of the Cascade range. Supper, amid rustic and massive surroundings, consisted of western chuck style barbecued salmon with all of the trimmings.

Ladies' Program

An outstanding program for women and children was planned by Mmes. Dunn, Pauley, May, Cornwall, Sackett, Proctor, West and others. It included, in addition to babysitter service, a combined breakfast and style show, luncheon on the Pacific Ocean, and cards at the Longview, Washington Country Club.

The *Wood* Award

Presentation of the *Wood* Award was made by Richard C. Art, Managing Editor of *Wood* Magazine prior to the Annual Business Meeting on Tuesday afternoon, June 27. The $500 award, presented annually for the outstanding thesis on forest products research submitted by students currently enrolled in any university or college, was won by Stephan B. Preston of the Yale School of Forestry and now an instructor at the University of Michigan. His thesis, "The Effects of Fundamental Glue Line Properties on the Strength of Thin Veneer Laminates", is reproduced in this Proceedings in Technical Session V. Second and third award certificates were won by S. K. Swamy of Yale, and V. H. Clausen, Jr. of the University of Minnesota.

Advisory Board Meets

Following the precedent set at the Grand Rapids National Meeting, delegates from each Section met with the Executive Board at dinner in the Blue Room of the Multnomah Hotel, Wednesday evening, to exchange viewpoints on problems and progress. Thirty-three men met under the Chairmanship of C. D. Stone. In the end the Advisory group made its recommendations to the Board concerning procedures on nomination and succession, collection of Section dues, publications and membership activities.

Executive Board

Both old and new Boards met at three adjourned sessions to transact current and future business. On Sunday and Wednesday evenings they met in Portland; and on Thursday and Friday went into all-day and evening sessions at the Hotel Monticello, Longview, Washington, closing after lunch, Friday, June 30.

Presentation of Papers

In the presentation of technical papers each author condensed his remarks to a ten-minute summary. This was followed by discussion from the floor, which was recorded. The complete papers, as published first in preprint form, are now reproduced in this Proceedings along with the discussion and the author's answers.

TECHNICAL SESSION I

Monday, June 26, 1950, 9:00 A. M.

General Subject: Logs, Sawmills and Lumbering

Chairman: H. F. Jefferson, Supervising Engineer, Nettleton Timber Company, Seattle, Washington

Recorder: R. A. Hertzler, Chief, Forest Utilization Service, S. E. Forest Experiment Station, Asheville, North Carolina (Board Member, Southeast Region, FPRS)

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E. G. Locke Presiding

Quality of Second-Growth Douglas-Fir and Suggested Means of Improvement

Benson H. Paul

Chief, Division of Silvicultural Relations, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture

Research at the U. S. Forest Products Laboratory has demonstrated that age and size are the main causes of difference between second-growth and old-growth Douglas-fir. Approximately 150 years elapse before Douglas-fir trees begin to produce clear, knot-free lumber of high quality characteristic of old-growth trees, some of which are 500 to 600 years old. The relationship between specific gravity and strength was found to be the same for both old and second growth; as a result of the greater proportion of wide-ringed wood in second-growth trees, however, more of it is of lower density than old growth, with correspondingly lower strength properties.

Introduction

SECOND-GROWTH Douglas-fir as defined by the Douglas-Fir Second-Growth Management Committee[1] refers to forest stands not older than the 160-year age class. The term is used synonymously with young growth and immature forests (Fig. 1).

The fact that timber is now being cut from stands much younger than the upper age class used in the definition suggests the present cutting of immature timber. Maturity is a relative term, however, the meaning of which will change from time to time with prevailing market conditions.

A question that needs a well-considered answer is: "What are the main differences between second growth and old growth?" The most obvious differences, of course, are size and age. Second growth (according to definition) may be as much as 500 years younger than old growth. Great variability exists in size-age relationships in both young and old stands.

Perhaps comparisons of young and old trees ought to be made first from an historical consideration of the development of trees and stands. Presumably the present old-growth stands established themselves following fire or some natural or accidental phenomenon that removed earlier vegetation and provided favorable areas for seed germination. In some cases the stands may have originated with dense, in other cases with sparse, stocking. The chances are that many old-growth stands originated under conditions not greatly different than those surrounding the beginning of the present young stands that have followed logging or fire, or both.

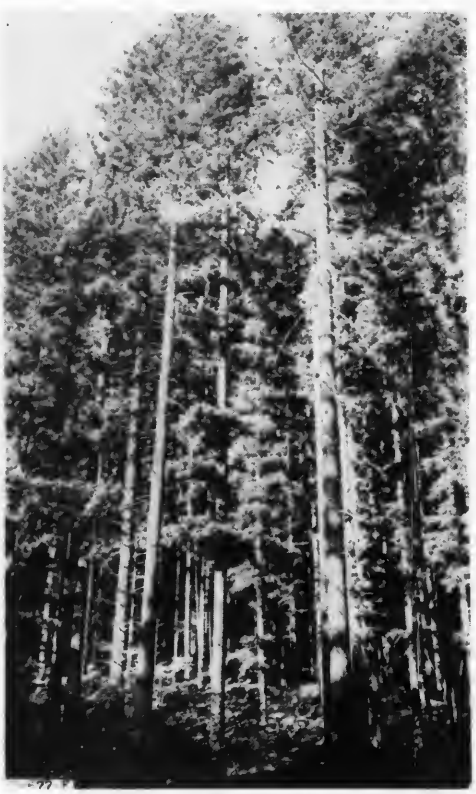

Fig. 1.—Douglas-fir second growth about 100 years old. Note the dead branches along the length of the trees.

[1] Forest Service. 1947 Management of Second-Growth Forests of the Douglas-Fir Region. Report of Pac. N. W. For. and Range Exp. Sta.

In the historical analysis of old-growth Douglas-fir trees, we usually find each of them consisting of three principal growth zones, the central, the intermediate, and the outer zone. We may describe each of these zones by certain characteristics related to wood quality. The central zone, or core, contains the area of branch origin and the intergrown portions of knots formed while adjacent lateral branches were yet alive. The number of rings may range from 2 to 25 or more per radial inch. Wood of the portion with the widest growth rings is likely to be near the lower limit of the specific gravity range of the species. This zone extends as a long cylinder from the stump into the crown of the tree. In general, it may last from 20 to 30 years at any particular cross section, sometimes much longer in widely spaced trees.

The second zone is characterized by knots from dead portions of branches. The dead branches are not connected by growth to the wood surrounding them. They are the source of loose knots or knot holes in lumber and veneer.[2] In Douglas-fir, this dead branch zone occupies a rather considerable volume of the tree (Fig. 2). Douglas-fir characteristically retains dead lateral branches for long periods, frequently for much more than 100 years. This dead branch zone is several inches in radial thickness outside the inner zone and extends the length of the tree from the stump to the base of the green crown. Wood of this zone may be below average in specific gravity for the species unless it has more than 10 rings to the inch.

Fig. 2.—Longitudinal section of a branch knot extending across a 13-inch radial section of a second-growth Douglas-fir tree 85 years old. This branch remained alive 30 years, to point indicated by arrow, and has persisted 55 years since it died. Its sound condition indicates that it might have remained on the tree many more years.

After occlusion of the dead branch ends, a third zone is formed which comprises the subsequent years of the tree's life. It is characterized by freedom from knots; its outer part is lighter-colored and known as sapwood. Whether heartwood or sapwood, this knot-free zone is the most valuable portion of the tree. It is the part from which high-grade lumber and veneer are obtained.

Studies of second-growth and old-growth trees indicate that the first two zones may have similar characteristics with respect to width of growth rings and persistence of dead branches. Second growth, however, does not contain any considerable proportion of wood in a clear zone and will not reach that stage of development for 150 years or more. This conclusion is based on an analysis of more than 1,000 knots in 100-year and 150-year stands.[3] Only a few branch knots were found to be overgrown, with the result that the lumber product from these two stands was primarily in the common grades. Likewise, high-quality face veneer was not obtainable from these second-growth stands. Products free from knots appear to be obtainable from second-growth Douglas-fir only when lateral branches are pruned artificially while the trees are of small diameter. Historically, then, the growth differences are the result of wood produced in old-growth stands that have passed the usual age of second-growth trees.

Width of Growth Rings

In second-growth stands, about three-fourths of the growth rings in trees less than 100 years of age were more than 1/10 inch wide. In old-growth trees, about three-fourths of the growth rings were less than 1/10 inch wide. In the central portion of the 100-year stand growing on site II, the wider rings were about

[2] Fleischer, H. C. Suitability of Second-Growth Douglas-Fir Logs for Veneer. Jour. of For., Vol. 47, No. 7.

[3] Paul, Benson H. A Study of Knots in Second-Growth Douglas-Fir. For. Prod. Lab. Report No. R1690.

⅓ inch in width. Rings ½ inch in width occurred near the center of old-growth trees. In the second-growth stand, growth rings gradually became narrower until, at 50 to 60 years, there were 10 or more to the inch. A similar reduction in ring width from 2 to more than 10 rings per inch occurred in the first 10 inches of radius of the old-growth trees. Subsequently, radial growth decreased rather sharply, but in second-growth trees there was much less narrow-ringed wood than in the old-growth trees. It appears to be the considerable proportion of rather slowly grown wood of uniform texture in old growth that is largely lacking in second growth.

Density and Summerwood Percentage

Generally, second-growth Douglas-fir density (specific gravity) and summerwood increased as the rings became narrower and from the center of the trees outward up to 80 years or more. Where growth in the last radial inch declined sharply both density and the proportion of summerwood decreased somewhat. In the 100-year stand, wood produced up to about 60 years of tree age was below the average for old-growth fir. A more slowly grown 150-year stand attained the old-growth average earlier, but because of lower site quality the trees were smaller. From the foregoing it is evident that second-growth trees less than 100 years of age may contain only relatively thin outer layers of wood equaling the average density of old growth, unless stand conditions during their early years of development are such that the radial growth of trees is restricted to about 10 rings per inch.

Comparisons of specific gravity and summerwood percentage indicated that wood with wide growth rings did not have so high a specific gravity as wood with narrow growth rings when summerwood percentages as determined on a radial line were equal. Thus, it appears that a specific gravity determination is a better criterion of strength than the percentage of summerwood, especially in wide-ringed timbers, where the change from springwood to summerwood is gradual and definite boundaries between springwood and summerwood do not exist. Doubtless it was the low density of wide-

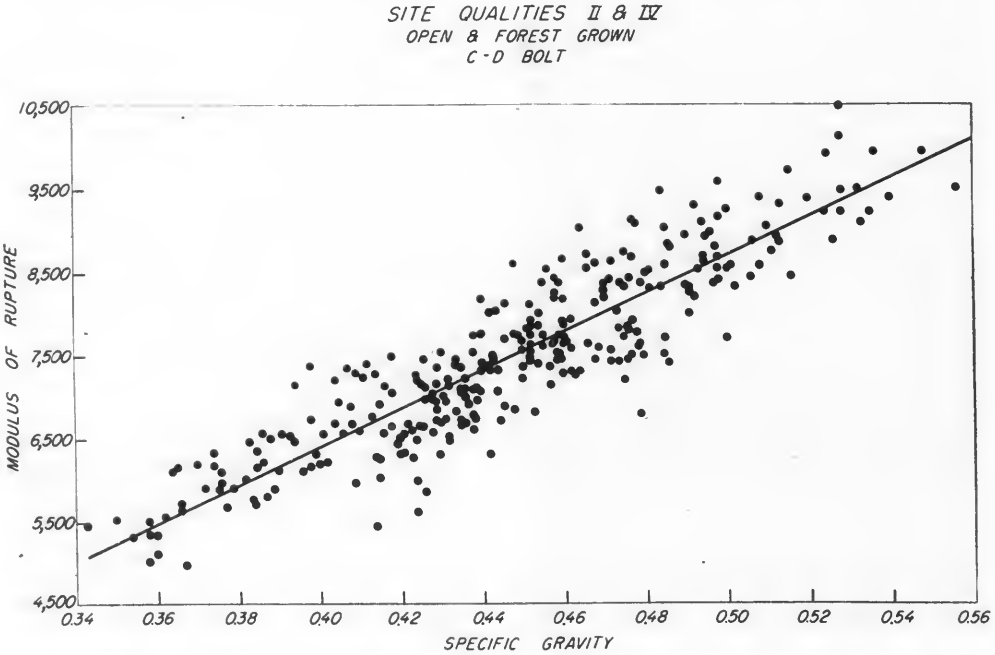

Fig. 3.—Modulus of rupture and specific gravity relationship in second-growth Douglas-fir from sites II and IV.

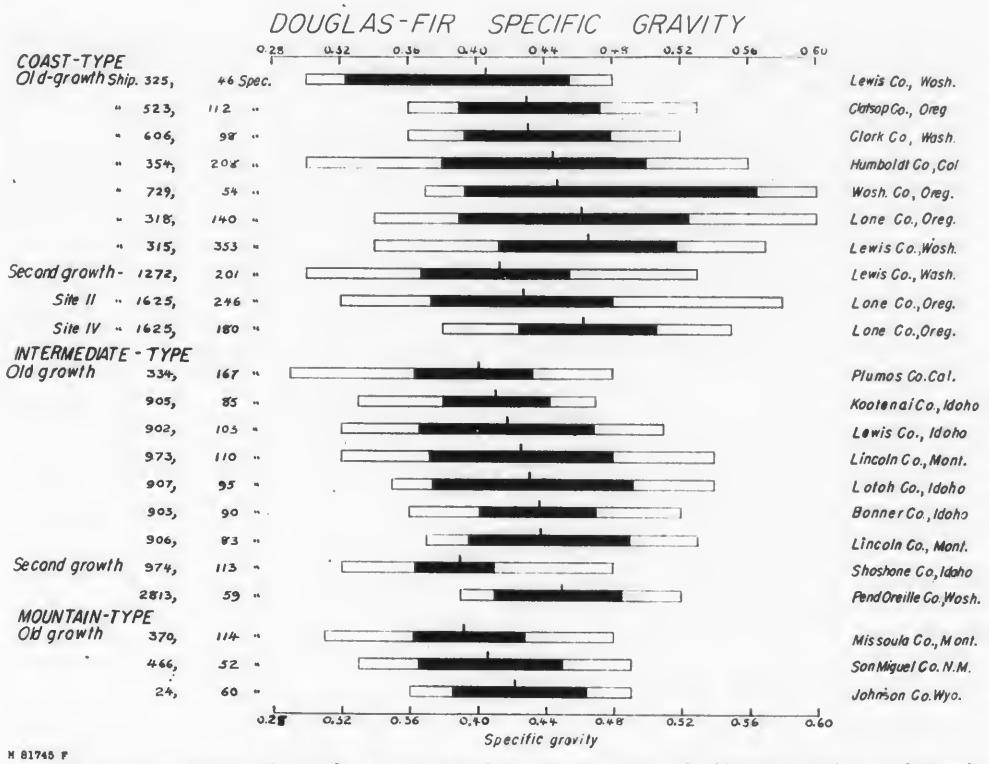
DOUGLAS-FIR SPECIFIC GRAVITY
0.28 0.32 0.36 0.40 0.44 0.48 0.52 0.56 0.60
COAST-TYPE
Old-growth Ship. 325, 46 Spec. Lewis Co., Wash.
" 523, 112 " Clatsop Co., Oreg
" 606, 98 " Clark Co., Wash.
" 354, 208 " Humboldt Co., Cal
" 729, 54 " Wash. Co., Oreg.
" 318, 140 " Lane Co., Oreg.
" 315, 353 " Lewis Co., Wash.
Second growth- 1272, 201 " Lewis Co., Wash.
Site II " 1625, 246 " Lane Co., Oreg.
Site IV " 1625, 180 " Lane Co., Oreg.
INTERMEDIATE - TYPE
Old growth 334, 167 " Plumas Co. Cal.
905, 85 " Kootenai Co., Idaho
902, 105 " Lewis Co., Idaho
973, 110 " Lincoln Co., Mont.
907, 95 " Latah Co., Idaho
903, 90 " Bonner Co., Idaho
906, 83 " Lincoln Co., Mont.
Second growth 974, 113 " Shoshone Co., Idaho
2813, 59 " Pend Oreille Co., Wash.
MOUNTAIN-TYPE
Old growth 370, 114 " Missoula Co., Mont.
466, 52 " San Miguel Co. N.M.
24, 60 " Johnson Co. Wyo.
0.28 0.32 0.36 0.40 0.44 0.48 0.52 0.56 0.60
Specific gravity
M 81745 F

Fig. 4.—Comparisons of specific gravity variations for shipments of old-growth and second-growth Douglas-fir from a number of locations within the natural range of the species. The short vertical line indicates the average, the solid bar the range of the middle 75 percent of the values, and the open bars indicate the extremes of range for each shipment.

ringed old growth that suggested the rings-per-inch and summerwood requirement of the density rule for structural timbers.

Relation of Density to Strength

The bending strength of the clear wood of second-growth Douglas-fir (as measured by the modulus of rupture) was found to be closely related to its specific gravity, or density. This is illustrated in Fig. 3, which is based on tests from stands growing on areas of site quality II and quality IV.[4] Specific gravity values ranged from 0.35 to 0.55 on the basis of oven-dry weight and green volume. Corresponding strength values for modulus of rupture for the above specific gravity range varied from about 5,000 to 10,000 pounds per square inch. It is interesting to note here that the results obtained in these tests of second growth were practically identical with results of early tests made at the Forest Products Laboratory on old-growth Douglas-fir. It must not be forgotten, however, that on a strength basis the main difference between old-growth and second-growth Douglas-fir lies in the greater proportion of low-density wood in second-growth than in old-growth Douglas-fir, especially in the faster-growing trees. In this connection it is important to point out that Coast-type second growth, if harvested at 100 years or less, will average considerably below old growth of the region in specific gravity and strength. In these respects it will have little, if any, advantage over Douglas-fir of the Inland Empire type. Also, because of the persistence of dead branches, second-growth Coast-type Douglas-fir will lack the advantage on a grade basis that has favored the old-growth stands.

[4] Paul, Benson H. Wood Quality in Relation to Site Quality of Second-Growth Douglas-Fir. Jour. of For., Vol. 48, No. 3.

Fig. 4 shows the overlapping specific gravity values of Douglas-fir, both old growth and second growth, from a number of locations in the natural range of the species. This chart is worthy of special study in consideration of the general changes in timber quality already mentioned that may come about in the Coast region as a result of the logging of young stands.

Sapwood and Heartwood

In second-growth Douglas-fir, sapwood ranged from 1 to 3 inches in radial thickness, being thickest in the trees that were largest in diameter at a given age. When computed on a cross-sectional area basis, sapwood constituted about 35 percent of the cross section regardless of the diameter of the trees. The proportion of sapwood is important in green Douglas-fir logs and lumber because of the great difference in moisture content of heartwood and sapwood. Moisture in heartwood averaged only about 35 percent of the moisture-free weight of the wood, whereas in sapwood it ranged from 120 to 150 percent, three to four times as much as in the heartwood. This greater amount of moisture in the green timber influences ease of handling and load limits of logs, as well as freight costs of lumber shipped green.

Conclusions

If old-growth quality is to be obtained in future second-growth stands, intensive forestry measures must be taken while the timber is growing, beginning when the trees are young. It will be advantageous to start with closely stocked stands, so that growth can be regulated and a desirable growth rate maintained by thinnings.

The trees must be pruned to remove lateral branches that persist and form loose knots in lumber and veneer. Pruning will be accomplished more quickly and the pruning wounds healed more satisfactorily if the pruning is done when lateral branches are very small.

The most rapidly grown trees at the start probably are not the ones that will produce the best lumber, because their growth rings are wider and their branches larger than those of their more slowly growing neighbors. For high density and strength, as well as for the best quality of veneer, growth rings need to be relatively narrow. Forest management, therefore, should aim not for the largest trees in the shortest time, but rather for a maximum production, per acre, of high-quality products over a reasonable rotation.

Nature is never in a hurry to accomplish her goal. The hundreds of years required in the production of clear old-growth Douglas-fir were no obstacle to nature. If we are to improve on natural methods, we must carefully consider the sequence of events that transpired in the old-growth forests and then devise means of obtaining similar results in a shorter time. If we neglect the practice of the best forestry methods and leave the job unaided for natural forces to accomplish, we must not be surprised if again hundreds of years are required to produce lumber of high quality in subsequent forest crops.

Discussion

Mr. T. E. Kelley (Washington State College): Are there not some disadvantages to thinning practices?

Mr. E. E. Matson (Pacific Northwest Forest Experiment Station): No, I think everything is on the advantage side. If thinnings are made properly, the yield of timber through the rotation period is greatly increased, and the final crop will be of higher quality material than in an unmanaged forest. Natural mortality in our second-growth stands amounts to about 1 cord per acre per year. Thinnings can be made which remove the poorer vigor and quality trees in the stand which will pretty nearly salvage the mortality, and leaving the better quality trees to grow will insure good quality timber for the final crop.

Mr. Kelley: Don't you bring down density of wood by thinning? If a hypothetical stand of second growth Douglas fir is thinned at 30, 40 and 50 years and is finally harvested at 60 years the final thinned stand will have approximately the same scale as the original stand would have had if there had been no thinning. This indicates that the thinned stand at 60 years will have fewer boles of greater unit increment hence these boles will have a lower

unit density. Moreover this lowering of density will be brought about by higher annual increments at points on the boles of trees effected by light which has come through breaks in the canopy due to thinning. This results in inconsistencies in wood density in the finished lumber and in warping. The conclusion drawn is that the gain in volume of timber equals the scale of the thinnings and the thinned stand at sixty years of age may be of greater value as pulp than it is as lumber due to the variations in density resulting from thinning practices. It is suggested that this may be overcome in part at least by thinning the subdominant trees and to preserve in every way possible the continuity of the canopy to maintain even increment in so far as is possible.

Mr. Matson: The effect of thinning on density depends on how you do it. If the stand is opened up too much, you will get wide ringed, coarse grained material which will have a lower density than trees grown well spaced with a closed canopy. If light, frequent thinnings are made which leave only small openings in the canopy, a uniform ring growth will be obtained that will have approximately the same density as adjoining unthinned timber.

Mr. B. H. Paul (Forest Products Laboratory, Madison, Wisconsin): Thinnings can be made to promote denser wood by removing larger rougher trees that have wide-ringed low density material in the center and leaving trees that have grown more slowly from the start with sufficient room to maintain growth at about 10 rings per inch.

Mr. H. F. Jefferson (Nettleton Timber Company): In the Douglas fir region on the Pacific coast, during the war years of 1941–45, a good deal of inferior lumber found its way to the market by reason of poor cutting practices of second growth stands. Numerous small Douglas fir stands were cut from trees that possessed considerable internal strain or compression wood, and the lumber coming from these trees showed an abnormal amount of spiral grain, and as it became dry, excessive twists, cupping and bow came into existence. Excessive twists evidenced themselves particularly when this lumber in 2 by 4 dimension was used in house framing. The problem is what can be done to recognize the existence of these fault producing characteristics in the tree. What factors produce twist, spiral grain, and strain? Can we recognize these properties?

Mr. Matson: Lumber cut from trees with spiral grain, compression wood, or marked differences in growth rate will have much more of a tendency to warp than lumber cut from trees with straight grained, uniform growth rates. I don't think anyone knows what causes spiral grain, and it is very difficult to detect in growing Douglas-fir trees. Compression wood is formed on the lower side of leaning coniferous trees. It also can be detected on the end section of the logs.

Uneven growth rates are usually caused by a sudden release of the tree. It can easily be detected by examining the annual rings. In sawing such timber an attempt should be made not to have marked differences of growth rate in the same piece of lumber.

Mr. Jefferson: I think the problem is deeper. You must look for more than cross grain. Some quick, practical means of recognition of the existence of these factors in a forest stand is necessary.

Mr. E. R. Linn (Oklahoma A & M College): Second growth with two rates of growth causes warping. How does one recognize it in the tree?

Mr. B. H. Paul: The cause of spiral grain is unknown. Some think it is hereditary. In ponderosa pine some trees were found to spiral less after they had accelerated in growth. Differences in slope of spiral grain in the same piece also causes warping. Unequal shrinkage in the longitudinal direction in different parts of the same piece causes much warping. Excessive endwise shrinkage is associated with exceptionally fast growth in the early life of some trees. Wood having wide rings on one edge of a piece and that having narrow rings on the other edge may shrink or swell in different amounts and thus cause warping. Another source of warping is compression wood that forms on the under side of leaning trees.

Mr. R. N. Hammond (Weyerhaeuser Timber Company): How about tons per acre per year? What is the relationship of tons of dry wood per acre per year produced with the silvicultural treatment to give high density wood as compared with the production of low density wood?

Mr. Matson: Provided there are enough trees to utilize the growing space, the volume of wood grown per acre does not vary with the number of trees. However, there will be a marked difference in the growth rate of individual trees depending on stocking. In other words, it is possible to get the same growth per acre on fewer faster growing trees than with more but slower growing trees per acre.

Mr. Hammond: In other words, you mean that although a more open stand would give lower density wood than a more closely grown stand the net amount of oven dry wood material in either case would be the same. The primary interest of the pulp producer as regards forest production and yield is not board feet or cubic feet per acre per year but tons of dry wood per acre per year. From this discussion it appears that the same tonnage would be obtained from either low or high density wood. The pulp makers interest would then lie in which type of wood produces the most desirable pulp properties.

Mr. Matson: As previously mentioned, wood from fast-grown Douglas-fir is less dense than from fast grown trees. However, if the stands are properly thinned so as to fully utilize the growing space, there is little danger of materially lowering the density of the wood being produced.

Dr. Edgar Mörath (Food and Agriculture Organization): We have had some experience in Austria regarding rate of growth versus warping. Average yield per ton was same for fast and slow growth.

Mr. A. J. Norton (Consulting Chemist, Seattle, Washington): What about replacing elements in the soil—soil depletion?

Mr. Matson: Growth of trees does not deplete the soil if you keep fire out.

Mr. H. Smith (L. R. Smith Hardwood Company): Do you take large or small trees?

Mr. Matson: In our thinning we have found that some trees of all sizes should be removed if you use vigor, quality, and spacing of the individual trees as a marking guide. If thinnings can be made at an early age—say 25 to 50 years when you have lots of healthy trees per acre—we recommend the cut be concentrated in the rougher dominant trees so that the better quality co-dominants will be released. This thinning of the larger dominant trees becomes more difficult as the stands get older as there are not enough healthy vigorous understory trees to fully utilize the growing space. This means that in the older age classes more of the trees removed will have to come from the intermediate and suppressed crown classes.

The four following simple rules form a pretty good guide for thinning second-growth timber:

(1) Remove the larger, rough, limby trees that will release healthy, better-quality trees.

(2) Remove merchantable-sized trees that are likely to die before the next cut. These should include trees dying from crowding, rot, or other causes, and leaners that may blow over.

(3) Remove badly injured and defective trees. This includes trees with conks, bad fire scars, and very crooked stems.

(4) Remove some of the trees in dense clumps so as to improve growing conditions for those of better quality. One caution here: Do not make openings that expose a tree on more than one side. Too severe an exposure causes a shock that may prevent maximum growth for several years.

Mr. Paul: The same number of tons per acre per year of high density wood of medium ring-width would require more trees than in the case of wider-ringed wood. In rapidly grown wide-ringed trees branches contain more of the total wood. Wood removed in thinning should be included in the total. The total wood production of an area depends upon the active crown capacity rather than upon the number of trees. This is covered in Forest Products Laboratory Report No. R1689.

Mr. Don Burnet (Oregon State College): What about pruning?

Mr. Matson: We believe pruning will pay although we have had less experience with it than with thinning. Work of this type should at least start on the better growing sites where chances for financial success are the best. Pruned stands should also be thinned so as to concentrate more of the growth on the pruned trees.

Mr. Burnet: How about the length of cutting cycle with pruning?

Mr. Matson: A pruned stand will probably be carried on a longer cutting cycle than a similar unpruned stand. The pruned trees will be producing high-priced clear material, and such trees can be carried beyond the maximum growth period and yet produce the greatest value per acre.

Mr. Ralph Kappler (Kappler Lumber Company): Does pruning cause rot?

Mr. Matson: We have several pruning experiments that were established in CCC days that are now 12 to 14 years old. Last fall we assisted our Forest Products Laboratory in the collection of pruned samples which they are analyzing to determine the number of years required to heal stub wounds, occurrence of rot, etc. These findings on rot are similar to those found by other agencies, that is: the occurrence of rot caused by pruning young Douglas fir is negligible.

Mr. Jefferson: In the Douglas fir region of the Pacific coast, the rate of growth of new stands now coming up, after the logging of the old growth stands twenty or thirty years ago is ten to fifteen times the rate of growth of the former stands. On the average, the old growth areas were producing lumber at the rate of 50 board feet per acre per year. The new stands are showing an average production of 500 to 750 board feet per acre per year. This high ratio of increased production is a far more important factor than is generally recognized when considering our forest resources. It can be viewed as meaning that in terms of our forests of a few years ago, we now potentially have ten to fifteen times as much forest.

Mr. Paul: Pruning practices should remove lateral branches at a time when it can be done at least expense, preferably when the trees are small and the branches about ½ inch in diameter. To get the most return in clear lumber, prune early and thin to promote the desired growth of pruned trees. The natural long time persistence of dead branches in Douglas fir stands indicates that there is not much risk from decay as a result of pruning. Studies of this phase of pruning are under way by the Bureau of Plant Industry, Soils, and Agricultural Engineering.

Mr. Norton: What is being done in the way of replacing trace elements and other fertilizing materials that may be depleted?

Mr. Paul: At present it does not appear to be necessary to add trace elements to forest soils. Decay of foliage and slash will return much of it to the soil.

Mr. E. D. Mörath: Experiences in Europe show that serious inconveniences arrive when parts of different growth rate are in one piece of lumber and secondly, that average growth in tons of dry substance per acre remains stable if you get small-ringed or wide-ringed trees.

Grading Problems That Challenge the Lumber Industry

R. P. A. Johnson

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Research points to grading problems that include multiplicity of grades, the use of nondestructive tests to improve selection, and effect of region of growth on strength. The final application of research to the solution of these problems lies with industry.

Introduction

THERE are a number of grading problems of vital interest to the lumber industry for which no solution, at least no satisfactory solution, has been evolved. This paper discusses a group of such problems. The problems discussed involve simplification and standardization of grades, more efficient selection or segregation for strength, the establishment of universal design grades and the variations in strength of the same species from different regions.

There is some question as to the value of presenting problems for which we have no answer or at least no satisfactory practical answer. The principal value of such a presentation is to stimulate the consideration of the problems and to search for solutions. Research can aid in obtaining solutions, but in the end it is industry that must put into practical application any solution that is proposed as the result of a research study.

Simplification of Grades

The multiplicity and complexity of grades and grading rules has created serious problems in the marketing of lumber. The industry has recognized that fact for many years. Back in 1922 an effort was made to solve the problem by the establishment of American Lumber Standards. American Lumber Standards only partially solved the problem. They standardized sizes and provided a broad general base grade classification for softwoods but they did not provide standard grades. There are still twenty or more sets of regional grading rules each of which contains a number of grade specifications that are not exactly duplicated in any other set of rules. In addition, two different basic principles are used in grade descriptions. They are description by example and by specification. The first describes the grade by use of typical examples of the type of boards the grade contains, the second specifies the permitted defects and specifically limits their size. The wide difference in the character of lumber in grades of the same name results in confusion, is annoying to buyers and users, and is the source of controversies as to the comparability of grades of different species.

A number of attempts have been made to compile a chart of comparable grades of yard lumber. None has been generally acceptable. U. S. Dept. of Agriculture Circular 296 "Standard Grading Specifications for Yard Lumber" published in 1923 presented a basis for standard grades. It was not acceptable because the regional lumber groups would not agree to make the changes in their grades that its adoption involved.

That is an excellent example of a principle I wish to emphasize. No matter how much research work is done, nor how promising a solution is proposed, the final solution of the problem lies with industry. Industry must take the proposal or findings and adapt them to commercial practice. That may involve changes in long established practices that require time, training, and a considerable outlay of funds.

The stress grades are better standardized than the yard grades. U. S. Dept. of Agriculture Circular 295 proposed four basic grades. American Lumber Standards adopted two of them as basic grades for the guidance of industry in the establishment of commercial stress grades. The stress grades of the regional lum-

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

ber associations conform to principles used in formulating the basic grades. As a result it is possible to make numerical comparisons of the stress grades of different lumber associations. The stress grades of different associations, however, differ both in description and in assigned stress. There are therefore no national standard stress grades.

Simplifying Strength Grading

The stress grades have become so complex and involved that even experts have difficulty in interpreting them. As originally proposed in U. S. Dept. of Agriculture Circular 295 in 1923 they were simple. The complexity has developed as the result of changes made to increase their efficiency. For example, in order to simplify the inspection of joist and plank grades so that only the two wide faces need be inspected the method of measuring knots and calculating grade ratios was changed from the method used in beams and stringers. It would be easy to simplify the grades by going back to the original proposal but that would involve a loss of efficiency. The problem is to simplify without loss of efficiency. That is a difficult job. Primarily it is an industry problem for it means changing the grading rules. We do not know how far you are willing to go in sacrificing efficiency for simplification.

Improving the Efficiency of Grading for Strength

There is still a wide range in the strength in timbers of a single stress grade. A stress grade therefore contains many timbers of high strength that are not used efficiently because, although their strength is high, the working stress permitted must of necessity be safe for the weaker timbers. For example, tests of a single grade of structural timbers from one species ranged in modulus of rupture from 2,896 to 13,920 pounds per sq. in. (Fig. 1). About 50 percent of those timbers could be assigned a working stress 40 percent higher than is now assigned them. The problem is to devise a practical method of selecting the high strength timbers in the grade that will insure that no timber below a given strength will be accepted. To attempt to do that by further refinement of grading rules may further complicate them to a point where they become impractical of application. The solution may be in abandoning the present specifications and substituting a noninjurious acceptance test. The only trouble with that solution is that we do not have such a test at present.

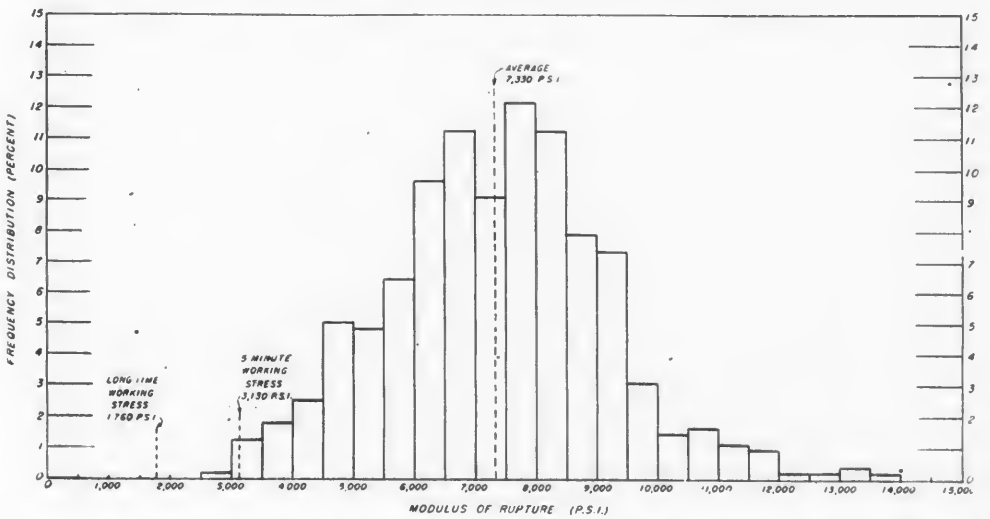
FREQUENCY DISTRIBUTION (PERCENT)
AVERAGE 7,330 P.S.I.
5 MINUTE WORKING STRESS 3,130 P.S.I.
LONG TIME WORKING STRESS 1760 P.S.I.
MODULUS OF RUPTURE (P.S.I.)

Fig. 1.—Frequency distribution of bending strength values in a single commercial structural grade (557 air-dry joists tested)

A specific gravity test on each timber or on a specimen from each timber would improve selection, even though specific gravity has its limitations as a criterion of quality. The industry, however, has considered such a method of selection impractical. A hardness test would accomplish about the same improvement in selection as specific gravity. The stiffness test, the effectiveness of which is not fully established, is generally considered impracticable of application and a hardness test is being developed but has not yet been perfected. Any of the three tests, if used, would only improve the selection in quality of clear wood and would not measure the effect of defects. Sonic and supersonic methods are being investigated in hopes they may furnish a means of predicting the strength of a timber both as to quality of clear wood and as to effect of defects. When and if sonic or other methods are devised to measure reliably the strength of a timber, the problem of using the method will then fall into the lap of industry. It will be industry's job to take the method and adapt it to commercial practice. After they have perfected the method they must be willing to pay the added expense its use will involve. It is evident, therefore, that any improvement in the selection of timber for strength that will permit increased working stresses and more efficient use can only be obtained by cooperation of research and industry and by some added costs.

Universal Design Grades

Designers, architects, and engineers want what they call universal design values. By that they mean they want a series of stress grades in 200-pound steps from about 800 to 2,400 pounds. To obtain that each regional lumber association would have to revise its stress grades to fit such a series. Such a scheme would enable a designer to select a stress and there would be several species that would have a grade carrying that exact stress. Under present conditions if a structure is designed for timbers carrying 2,000 pounds per square inch, fiber stress in bending, only one species lists a grade with that exact stress. If any other species is used a grade assigned a higher stress than is required must be used. It is obvious why the consumer does not like that.

The solution of the problem of universal design grades is not so simple as many consumers believe. Any scheme for the realinement of the stress grades presents a problem that involves revision of grading rules. There is, however, sufficient data available on which to base the establishment of universal design grades.

Universal design stress values do not solve the problem of multiplicity of stress grades. Since different species have different basic stress values, each species yielding a 1,000 pound grade would have a different set of rules, with different permitted knot and other defect sizes. There would thus be as many different stress grades as there are now but they would be much better interrelated.

The use of a geometric progression ratio applied to basic stresses and grade ratios has been suggested as a possible solution to the problem of universal design and standard stress grades. That scheme would involve the establishment of a series of basic stresses such that each basic stress multiplied by a fixed ratio would give the next lower basic stress. Similarly a series of grade ratios would be established such that each ratio multiplied by the same fixed ratio that was used to obtain the basic stresses would give the grade ratio of the next lower grade. Multiplying the basic stresses by the grade ratios would result in a series of working stresses that would be fixed so long as the basic stresses and grade ratios remained unchanged. The working stresses thus obtained could be used as universal design stresses and commercial grades could be drawn around them. To illustrate, if ¾ were selected as the fixed ratio to be used in obtaining the basic stress and basic grade ratios the following tabulation of bending stresses shows how the scheme would work. The values shown in the tabulation are not a recommendation or even a suggestion. The only purpose is to show numerically how the scheme could be applied.

Column 1 Basic stress clear wood		Column 2 Basic grade-ratio		Column 3 Uniform working stress
2000	×	75	=	1500
1500	×	56	=	1125
1125	×		=	840
	×		=	630

Any basic stress in column 1 multiplied by any grade ratio in column 2 will equal one of

the working stresses in column 3. Column 2 thus represents a set of possible standard stress grades and column 3 the universal design stresses. Information is available that makes it possible to draw specifications for commercial grades for any or all of the working stresses shown. Whether it is practical or not depends on whether industry representatives and others concerned can agree first on the basic stress and basic grade ratio to be used, and most important, on whether the lumber industry believes the consumer demand for universal design stresses and standard stress grades and the benefits that would result from their establishment are sufficiently important to justify a revolutionary revision of all stress grade descriptions.

Variation of Strength of Species From Different Regions

The lumber industry and users have from time to time placed considerable emphasis on the effect of region of growth on the strength of the wood of a species. Frequently lumber from one region has brought a premium over lumber of the same species from other regions. So far as strength is concerned, with a few exceptions, the data show no significant difference. The few exceptions however create a difficult problem.

Region of growth is not a satisfactory or efficient method of segregating lumber or timber for strength. There is no way of telling from the wood where it grew and when wood of the same species from different regions goes to the same distribution point high and low strength material may become hopelessly mixed. Regions of growth are seldom accurately defined. Terms such as Appalachian oak, Arkansas soft pine, or North Carolina pine are indefinite. There is a tendency to extend the boundaries of the regions of both high and low strength material which results in controversies. Lastly, even though there may be a pronounced difference in the strength of the wood from different regions, no region has a monopoly on all the high or low strength material.

Naturally producers of high strength timber in any region want the quality of their timbers recognized by increased working stresses. The problem is how can such high strength material be selected or described. A division into regions leads to confusion and complicates rather than solves the problem.

The establishment of a single working stress for timbers from different regions that differ widely in strength is not a satisfactory solution. Working stresses are based on the premise that every timber must safely carry its design load. If the weaker timbers of a region are included with stronger timbers of another region under a single working stress then the working stresses must be low enough to be safe for all of them. That means inefficiency in use of the stronger timbers.

We have reanalyzed the data on several species in an attempt to find a visual method of identifying the stronger timbers. The relation of rings per inch, density, and combinations of these to strength were studied. So far no relation has been found that would form a satisfactory practical basis for more efficiently segregating high strength material than systems now in use. Specific gravity could be used as a basis of segregation but so far no method of using it has been found which seems practical. The problem of utilizing the higher strength material of any species cannot be solved permanently and satisfactorily by segregating on the basis of region of growth.

Summary

The solution of the simplification and standardization problems discussed requires cooperation of the lumber industry as a whole. The strength problems point to the need of a nondestructive test and no satisfactory one is now available. Until such a test is developed, highly efficient segregation of high strength timbers appears unlikely.

The final solution of each of the problems presented lies with industry. Research can help by pointing the way but no matter how exhaustive the research nor how promising the findings, putting them into practice will involve changes in established practices that can only be made by industry.

Discussion

Mr. H. F. Jefferson (Nettleton Timber Company): More "wood consciousness" everywhere is needed. We need more education, a broader knowledge of wood and its wonderful properties among users. For example, the fact that nothing can take punishment like wood.

Mr. R. C. Fraunberger (Philco Corporation): Shouldn't we try to find better ways to merchandize our products? Don't we need changes in terminology? Let's sell customer values.

Mr. F. J. Hanrahan (National Lumber Manufacturers' Association): Mr. Johnson has presented problems that are a challenge to the lumber industry: (1) Simplification of grades. (2) Improvement in efficiency of stress within grades. You must have research data on which to base adequate promotion of product. Industry is making progress and will depend on research. We would like to know the effect of rings per inch on grade for second growth.

Mr. Fraunberger: We really are putting out "over-quality" material at too low cost.

Mr. K. W. Guenther (Seaboard Lumber Company): Other industries narrowed margins but they have spent money in research to do it. Lumber spends less than one percent of sales for research.

Mr. L. A. Nelson (Lumber Consultant): I agree with Mr. Johnson on the necessity for simplification of grades. However, we must simplify the presentation of grades.

Mr. H. V. Simpson (West Coast Lumbermen's Association): I too agree with Mr. Johnson's challenge, but progress is being made. For example, in the matter of glamorization of lumber, our association is now producing full-color booklets and ads in leading magazines glamorizing the use of wood in the home and products of the home.

Mr. Guenther: Mr. Jefferson mentioned that other industries have reduced the quality of their product so that the product will perform only a rated service, no more. We know that the lumber industry very often under-rates its products because of a lack of product control and a lack of research. Most other industries sow back, into their research program, one percent of their sales. The research pays for itself. The lumber industry is very far under this average of one percent of sales. This situation must be corrected to improve the position of the lumber industry in competition.

FOREST PRODUCTS RESEARCH SOCIETY

Quality Control and the Improved Seasoning Processes of the Redwood Industry

Byrne C. Manson

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Recent test work in the drying of redwood shows that the highest quality results are obtained by air seasoning and then kiln drying under a schedule in which the drying rate is controlled. Proper segregation of the green lumber for air drying, proper air drying procedure, and certain kiln characteristics are essential for quality and economical work.

Introduction

FOUR general considerations must be taken into account to obtain the desired quality and most economical results in the drying of redwood: 1, segregation of the green lumber; 2, sticking, stacking, and handling of the lumber; 3, air seasoning; 4, final kiln drying.

Segregation of Green Lumber

The first problem which must be given attention is the sorting of the green lumber into proper drying segregations. The lumber characteristics which affect drying time and drying degrade are: 1, weight of the green wood; 2, rate of growth or number of rings per inch; 3, intensity of color.

Tests have shown that boards of high initial weight require longer drying time because the weight is due to specific gravity of the bone-dry wood, to moisture content, or to both. Boards of high specific gravity have a slow transfusion rate and consequently a low drying rate compared to boards of similar moisture content but lower specific gravity. Boards of high moisture content have a transfusion rate proportional to their moisture content, but due to the excess moisture, they require longer drying time than pieces of similar specific gravity but lower moisture content. High weight, therefore, regardless of its cause, may be taken as an indication of slow drying. In order to have all of the boards in a given charge reach the desired moisture content at approximately the same time, it is essential that the initial weight of the boards be in the same general class. Green redwood varies in weight from less than 3 pounds to more than 6 pounds per board foot. The number of weight segregations possible is infinite, but for practical drying three segregations are usually made; light, medium, and heavy. The basis of these segregations is as follows:

Light—less than 3.5 pounds per board foot.
Medium—3.5 to 5 pounds per board foot.
Heavy—over 5 pounds per board foot.

The reason that the number of rings per inch and the intensity of color affect the drying rate is not as clearly understood. However, tests have shown that very fine-grained pieces will have a lower drying rate than pieces with fewer rings per inch, if all other characteristics are equal. In practice, this fact may be taken into account by placing pieces which are otherwise on the borderline of weight between two segregations into the heavier segregation if they have 50 rings per inch or more. This is determined visually without difficulty because boards with over 50 rings per inch have a very close-grained, fine-textured appearance. Color is taken into account in segregation in a similar manner. If pieces are on the borderline in weight, those of deep color are placed in the heavier, rather than in the lighter segregation.

If this segregation problem is given the attention it merits, the quality of the final product is improved by as much as 10 percent in value. One-half of this improvement will be evident in less degrade; for example, the elimination of collapse, split birds-eye, checks, and stains. The other 5 percent of improvement will be evidenced in the elimination of wet lumber or pieces with wet cores which will inevitably result from mixing pieces with slow-drying characteristics with more rapid-drying stock.

Lumber Handling

Handling of the lumber after the segregations are made should be subject to the same careful control required for economical drying of any species. The stickers should be of uniform width and thickness and their alinement in the package should be as perfect as possible to eliminate warp. The usual sticker size is 1 inch thick by 2 inches wide. Transportation to and from the air yard and stacking and unstacking at the air yard and kiln should be done as carefully as possible to prevent misalinement of the stickers and to insure proper placing of the stickers over the bunks and bolsters.

Air Seasoning

The air yard should be so laid out that maximum air circulation is provided around the piles and the volume per acre should be limited so that the air drying will proceed rapidly. Rapid, uniform air drying will be evidenced by improved quality in the final kiln-dried product. The actual lay-out of the yard and the optimum footage stacked per acre depend upon local climatic conditions and cannot be stated generally. However, footages between 750,000 and 1,000,000 per acre appear satisfactory.

It has been found possible to kiln dry redwood green from the saw with degrade of 1 percent or less, but this procedure is not economical because of the excessive kiln time required. Preliminary air seasoning to a moisture content of approximately 50 percent prior to kiln drying has been shown to produce the highest-quality product at minimum cost. At this condition, the variability of moisture content which existed in the green lumber has been reduced to a satisfactory minimum and the subsequent kiln drying can be carried out with reasonable speed and good control over the quality. If kiln drying of air seasoned lumber is attempted at some moisture content above this point, the kiln time is excessive and some types of degrade cannot be eliminated with certainty. Brown stain is the most noticeable of these conditions. Air seasoning the lumber to a moisture content below 50 percent usually requires excessive yard-drying time, particularly in the high humidity prevailing in the coastal areas where the species is milled. The excessive time is undesirable because of the cost involved and because it tends to give rise to air-seasoning defects such as checking.

Proper Kiln Characteristics

The kiln characteristics which redwood requires are similar to the characteristics required by the kilns for handling other softwoods. The air circulation should be uniform and of a velocity of not less than 250 feet per minute through the lumber. Circulation rates lower than this do not produce uniform drying without excessive time and the consequent higher kiln costs and more degrade. Rates above 250 feet per minute and up to 500 feet per minute do not show a great decrease in drying time, but they do show an increase in the quality of the lumber. Lumber can be dried in kilns having 500-foot air velocity with degrade losses in the neighborhood of 0.5 percent of the lumber value. This has not been possible in kilns with low circulation rates without taking excessive drying time, and even then it is doubtful if it can be done consistently. The higher air circulation also shows considerable improvement in the uniformity of the drying. At 250 feet per minute, the maximum variation was found to be 7.2 percent moisture content at an average moisture content of 8 percent. At an air velocity of 500 feet per minute, this variation was reduced to 3.7 percent. The higher air velocities also show a considerable improvement in the overall quality of the drying as indicated by the following analyses:

Defect	Percent of Total Number of Pieces Showing the Defect	
	Air Velocity 250 Feet Per Minute Percent	Air Velocity 500 Feet Per Minute Percent
Stain	5.5	0
Collapse	4.0	2.4
Check	2.1	1.2
Birds-eye	2.5	3.9
Total	14.1	7.5

Due to the fact that the higher air circulation shows the reduction in over-all degrade and an increased uniformity of drying, the higher air-circulation rates are justified from an economical point of view. The savings in degrade and the increase in uniformity more than justify the additional power cost necessary to obtain the higher air circulation.

The heating system should be adequate to produce any range of temperature from 110° F.

dry-bulb on the green lumber to 180° F. on the dry lumber, and the uniformity of temperature throughout the kiln should be of a very high degree. Redwood is particularly sensitive to temperature during the high moisture content stages. The sensitivity is evidenced in the form of collapse, split birds-eye, and stain, all of which affect the quality. The temperature throughout the kiln must be controlled and uniform to eliminate the possibility of spots in which the temperature exceeds the desired schedule. The lumber in such areas will show evidence of the degrades mentioned.

The venting system should be adequate to produce a wet-bulb depression of 20° F. on green lumber with a dry-bulb temperature of 110° F. Failure to achieve this condition will result in slow drying and may give rise to stain. The humidifying sprays should be adequate to hold a 5° F. wet-bulb depression at 165° F. dry-bulb temperature when the lumber is dry. If this condition cannot be reached, it is not likely that all the stresses will be relieved and losses will develop in remanufacturing, particularly in the manufacture of resawn siding.

Schedule Determination

The last condition which affects the quality of the drying is the temperature schedule used in the kiln. This factor is the most difficult to evaluate and to answer satisfactorily. The other conditions, segregation, handling, yard drying, and kiln characteristics, are more or less mechanical and each variable can be refined independently of the others. With the kiln schedule, the problem is quite complex because the three variables, temperature, humidity, and lumber moisture content, may all be varied independently, but the optimum result in quality and economical drying depends on an ideal set of relations between the three for the various phases of the drying.

The determination of an ideal relationship between the three conditions has been the subject of considerable test work. In the work which has been done on redwood, an effort has been made to determine a basis for development of a satisfactory schedule. A method was sought which could be based on an established physical law. The results have been quite satisfactory. Several basic physical conditions which influence the drying of wood were investigated. A single condition was finally selected as the basis for scheduling because it is the most elementary of the physical laws, and by following it, lumber was dried with the highest degree of control over both quality and drying time. This particular law states that loss of moisture content per unit of time will be proportional to the residual moisture content. It is the same law that controls the disintegration of radium and the transfer of heat from a hot to a cold body. The rate of transfer is proportional to the residual.

The drying of lumber is, of course, an extremely complex process, but it is believed that this single law expresses the reaction as simply and as accurately as any mathematical relation can express it. The test data fall quite closely in line with the pure theory. The digression of the test results from the theoretical prediction can be explained by the fact that the theory assumes all cells in a similar position in the board to be of the same moisture content at any time; this is not true because of the natural variation in moisture content and drying rate throughout a given board and, to a greater extent, throughout the boards of one charge.

The theory states that the loss of moisture content per unit of time, or the drying rate, shall be proportional to the residual moisture content. Since the drying rate is proportional to the moisture content and the drying rate is the rate of change, or first derivative of the curve of moisture content against time, this curve is a logarithmic function, and the relation between the drying rate and the moisture content, the drying-rate factor, is a constant. This may be shown mathematically:

where $T =$ drying time in hours

$M =$ moisture content in percent at any instant

$$T = k \log M + c$$

$$dT = \frac{k \log e}{M} dM$$

$$\frac{dM}{dT} = \frac{M}{k \log e} = \text{Drying Rate}$$

$$\frac{\text{Drying Rate}}{M} = \frac{1}{k \log e} = \text{Drying-rate Factor}$$

$$k = \frac{\text{Hours to reach 10\% M.C.}}{1 - \text{Log of original M.C.}}$$

$c = -$ K log of original moisture content

It is in the development of this relation that the discrepancy between theory and practical work develops. The above development shows that the drying-rate factor is a constant since it depends on "k" and "log e", both of which are constant for any given species and size. In practice, it has been found possible gradually to increase the factor as drying progresses without damage to the lumber. As noted previously, this is believed to arise from the fact that the drying-rate factor can be gradually increased as the moisture content falls, because the moisture content is constantly equalizing and the possibility of damaging the lumber, due to forcing the drying of wet spots, is constantly reduced.

The theory gives only part of the information necessary to establish the schedule. It shows that the drying-rate factor should be a constant and that the drying-rate curve, plotted against time, should be a smooth curve, with moisture content the only other variable. It does not fix the drying-rate factor unless the time required to dry a charge with minimum loss of quality is known. This must be determined by test. Fig. 1 shows the type of test data taken for this purpose. The particular data are for 1-inch redwood. The drying rates are determined for various combinations of wet and dry-bulb temperatures at various moisture contents, and curves, which approach straight lines, are drawn through the points of constant wet and dry-bulb temperature. The points along these curves at which degrade appears are then plotted and the "actual schedule" curve is drawn through the points. The "theoretical schedule" curve is also shown on Fig. 1. This is a straight line determined by the purely mathematical equation and the drying-rate factor developed from it. The actual schedule lies below the theoretical schedule on the temperature scale in the higher moisture content ranges, and above the theoretical curve in the lower ranges.

The determination of the final schedule is made by using the temperature setting indicated by the intersections of the actual schedule curve with the temperature lines above each moisture content stage. In practice, the application of

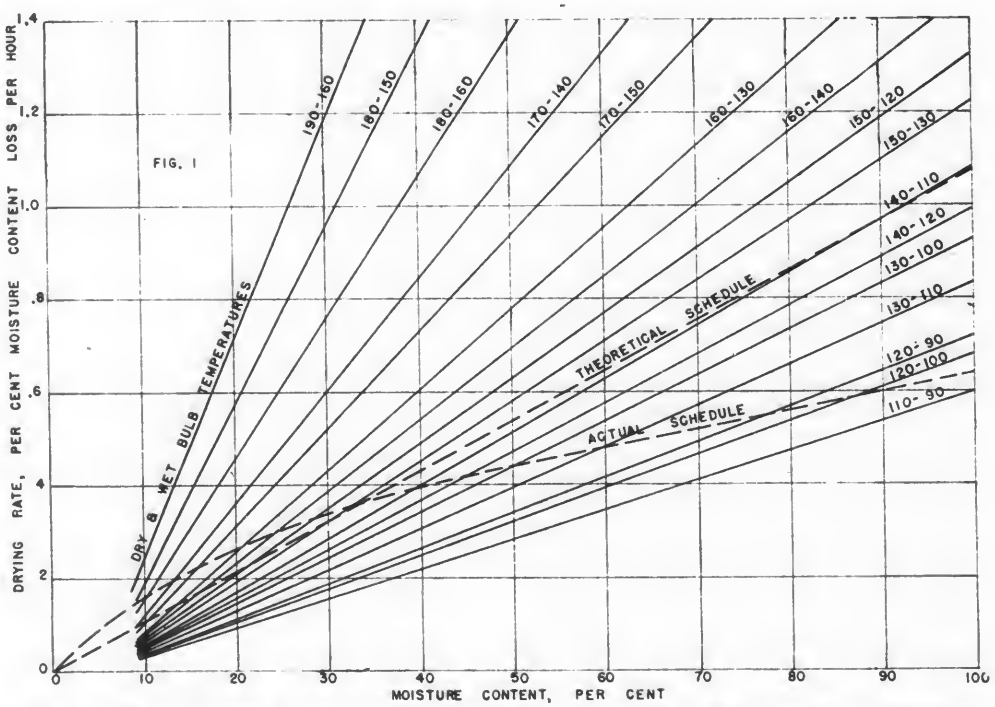

Fig. 1.—The drying rate of 1-inch redwood under various wet- and dry-bulb temperature combinations.

this drying-rate method of schedule determination is quite simple. Once the curves of drying rate have been plotted for the particular kiln plant and species, as shown in Fig. 1, and the basic schedule line has been drawn across these curves, then schedules faster or slower than the basic may be readily determined by drawing a family of curves around the basic schedule curve. The other curves of the family will simply represent schedules which will produce higher degrades and require less kiln time or produce lower degrades and require more kiln time. Due to the high value of redwood, it has generally been agreed that the schedule producing degrades of 1 percent or less of the mill base price of the lumber produces the most economical drying. This point has been taken in determining the basic schedules, and it is the one most generally accepted. The schedule which develops from this method has two noticeable characteristics that can be used to check the accuracy of any new schedule which may be proposed. There are (1) the drying-rate curve plotted against time, which should be a smooth curve without hips and valleys; and (2) the curve of drying rate factor plotted against time, which should be a straight horizontal line or a gradually increasing curve without sharp breaks.

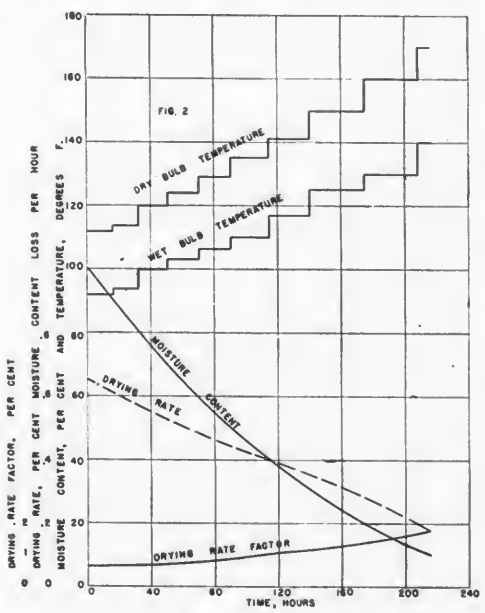

Fig. 2.—Results of drying a typical charge of 1-inch redwood by using a controlled drying rate.

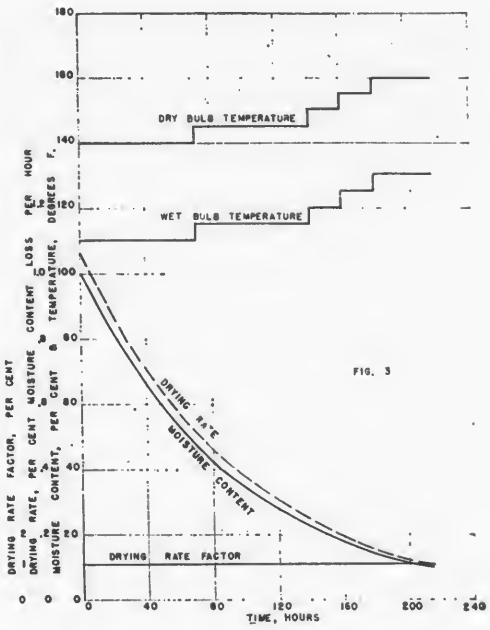

Fig. 3.—Results which would be obtained from drying a typical charge of 1-inch redwood by using the purely theoretical schedule.

The schedule which fulfills these conditions will always be one in which the temperature rises gradually and at an increasing rate, and the wet-bulb depression increases gradually and at an increasing rate. Fig. 2 shows the results of using these data on an actual charge. The curves of moisture content and drying rate are smooth and gradually decreasing. The drying-rate factor curve is smooth and gradually rising. Fig. 3 shows the plot of the theoretical schedule. These curves represent what we should get from an ideal schedule but they do not take degrade into account. The differences which are shown between Fig. 2, the actual schedule, and Fig. 3, the theoretical schedule, are caused by the fact that the initial moisture content and drying rates are not uniform throughout the charge, and in consideration of this fact the actual schedule must be altered from the purely theoretical one by decreasing the drying rate in the early stages of drying and increasing the rate in the later stages.

Fig. 4 shows the results of using a schedule which makes no effort to keep a uniform drying-rate factor. Experience indicates that lumber dried with reference to a uniform drying-rate factor will be dried either in less time or with less degrade, or both, than if it is dried under a schedule not based on this control. This may be explained by referring to Fig. 4. If the lumber could not stand a higher rate than that shown at point *B* at that particular moisture content, then it will be damaged a few hours later by the drying rate attained at point *A*. Conversely, if the drying rate at *A* produced no noticeable degrade, the lumber was not being dried to its maximum rate at the time it passed point *B*, and kiln time was being wasted.

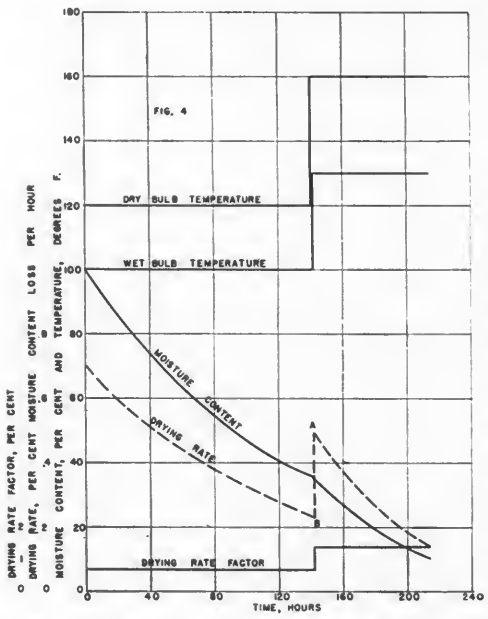

Fig. 4.—Results obtained by using a schedule which makes no attempt to maintain a uniform drying rate.

Summary

The drying of redwood is complicated by the fact that the moisture content, specific gravity, ring count, and color intensity vary between wide limits in the green lumber. The first problem is to segregate the green lumber into groups with drying chacteristics as similar as possible. The second problem is to give proper attention to the sticking and handling to prevent warps and splits. The third point to consider is proper preliminary air seasoning to equalize the moisture content as closely as possible to an average of approximately 50 percent prior to kiln drying. The kilns used in final drying should produce a high degree of uniformity and adequate values of temperature, humidity, and air circulation. The schedules used in the kilns should follow the drying-rate method, which gives a uniformly falling drying-rate curve dependent upon the residual moisture content.

Discussion

Mr. R. C. Fraunberger (Philco Corporation): Is the paint holding property of redwood dependent primarily on its dryness? Immediately after the war redwood siding shipped to the East Coast in many instances has failed to hold paint. What can be done to remedy this situation?

Mr. Manson: Paint will not hold satisfactorily on wet wood. Blistering and staining are most common failures. Wood can get wet in service in homes by leakage of vapor and moisture barriers and poor joints. Either this moisture or that residual from poor original drying will cause paint failure.

Mr. G. G. Garlick (Protection Products Manufacturing Co.): Water repellent preservative treatments have met with success. Today, siding, trim, millwork and other similar items are being treated to protect against blistering, peeling and staining caused by excessive moisture content.

Mr. Manson: They aid in preventing reabsorption but should not be depended on to correct faulty original drying.

Mr. H. F. Jefferson (Nettleton Timber Co.): Do you measure drying rate by sampling? Isn't there an easier way giving a constant record? At the Nettleton Timber Company plant we have for the past fifteen years used a simple device for continuously indicating the average shrinkage of the stock being dried. This is accomplished by a simple lever device multiplying by about ten times the actual shrinkage of all the lumber comprising one vertical face of each kiln car. Because a large number of pieces

come within the range of the device, it successfully averages the shrinkage. We also have equipment providing for electrically recording the shrinkage on a continuous chart. By these ways we are kept constantly informed of the rate of drying of our lumber and its average dryness at any particular time.

Mr. Manson: We also measured shrinkage, but no recording method is available. Shrinkage correlates at times of rapid change. We need a device for recording moisture content. We also used thermocouples. At present, constant sampling on a weight-moisture content basis is most reliable.

Mr. J. Tudor (Westinghouse Electric Corporation): Has acceleration of drying by mechanical agitation been tried? If so, what types were tried and what were the results?

Mr. Manson: We have tried high frequency but the cost is too high. The electric power requirement is excessive.

Mr. Jefferson: Amongst various methods of drying there has been considerable reference in recent years to the use of radio frequency heating. All efforts in this direction, related to the quantity manufacture of lumber, have shown that the method is far too costly as a means of generating heat for drying. Some investigation of the use of sonic and supersonic energy is now being made in connection with reducing the time of impregnation of wood by various liquids.

Mr. Tudor: Has any effort been made to accelerate drying by using sound vibrations? Has any effort been made to accelerate drying by using radio frequency heat? Power costs are prohibitive using radio frequency heat alone, but a combination of air dry with a radio frequency heat or vibrational heat could be economically justifiable and might give better drying control.

Mr. Manson: Radio frequency was analyzed but not followed through due to the cost of power. High frequency sound has not been tried as far as I know.

Mr. William J. Baker (Oregon Forest Products Laboratory): Because of the extractives in redwood, the fiber-saturation point, as determined by shrinkage measurements, is about ⅔ that of other woods. Have you noted any tendency for the light-colored, light-weight material having lower extractive content (and probably a higher fiber-saturation point) to check more easily than the heavy, dark-colored wood?

Mr. Manson: Any difference in tendency of boards to check is more dependent on hard streaks than on extractive content.

Mr. Baker: Since your redwood schedule has virtually a constant wet-bulb depression, the equilibrium moisture content is almost constant throughout the run. Many species cannot be dried to a low moisture content or in a reasonable time with this type of schedule. Would you care to comment about your results on redwood?

Mr. Manson: High equilibrium moisture contents have been found desirable to eliminate wet spots without collapse or checked birdseye. These defects, rather than checking, control the drying rate and therefore, the equilibrium moisture content is used in the schedule. Lower equilibriums, particularly at the end of the run, are being investigated.

Mr. Baker: Are the printed formulae free from typographical errors? For example, do the logs refer to the base "e" as well as to the base "10"?

Mr. Manson: As shown, the equations are to the base "10". The base "e" may be used just as well. By using the base "e", the values of "k" would be changed. If the natural log to the base "e" were used, the term "log e (to the base 10)" would drop out of the equation. Log $_{10}$ e is a constant and its removal would only effect the value of the constant "k".

Sawteeth in Action

L. H. Reineke

Technologist, Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

Studies of the cutting action of a single sawtooth led to the development of the Forest Products Laboratory Duo-Kerf rip saw. This experimental saw offers smoother surfaces, reduced power, increased accuracy, and reduced kerf over the conventional saw.

Introduction

THE U. S. Forest Products Laboratory is dedicated not only to the better utilization of the lumber turned out by our sawmills and other wood-producing plants, but also to the better utilization of the logs produced in the forests by nature or by the efforts of our foresters. Much—too much—of the harvested trees appear as scrap in converting them into useful articles. Part of this scrap is forced on us by the round, tapering, irregular form of the raw material, about which little can be done immediately. The rest of this scrap is caused by machinery, about which something can be done.

The sawmill is our most talked-about scrap producer, but the directly visible slabs, sawdust, edgings, and trims that give it this prominence are not the only scrap the sawmill produces. Rough, inaccurately sawed lumber makes the user of rough lumber think of substitutes, or makes the planing mill groan to convert the excess thickness of poorly cut boards into shavings in order to make acceptable finished lumber. How important this can be is shown by the work of C. J. Telford, small sawmill specialist of the Laboratory, who has studied the variation in thickness of the boards produced at sample mills of different types.

Fig. 1 shows the number of boards by thickness classes produced by a sash gang mill and six portable circular mills in aiming at the production of nominal 1-inch boards. Now, if the thinnest boards, the left-most class in each graph, are the thinnest that will dress out to finish size, every thickness class to the right includes some excess material. If we multiply the excess in each thickness class by the number of boards in that class, and take the total, we find that the sash gang uses a total extra thickness of 4⅛ inches per hundred boards and the portable circular uses 22⅛ inches, all of which the planer has to make into low-value shavings, in addition to the minimum dressing required to clean up the boards. If, to these hidden scrap figures,[2] we add the kerf taken out by each mill (⅛ and $\frac{9}{32}$ inch), the total scrap chargeable to sawing becomes 16⅝ inches per hundred boards for the sash mill and 50¼ inches for the portable mill, a ratio of 1 to 3. Considering both sawing inaccuracies and kerf, it becomes evident that the sawing operation is not uniformly at its best. What can be done about it?

Something Done About It

The Forest Products Laboratory has been doing research on saws and other cutting tools for several years. Work with portable mills has been separately reported.[3] Concurrently, investigations are being made of the basic relationships between the physical characteristics

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] By reducing the circular saw set-over for each cut by $\frac{3}{32}$ inch, the three thinnest boards will be undersize and perhaps only partially usable, but the $\frac{3}{32}$-inch saving on each of the 100 boards will save 9⅜ inches of material from which an additional 6⅔ boards per 100 (including their kerf) could be cut. Trading better than 6 boards per 100 for 3 partial or even complete rejects would seem to be good business. With the sash-gang saw, a reduction in saw spacing of $\frac{3}{32}$ inch would yield a net gain of 1¼ boards per 100 provided the resulting 5 undersize boards were dressed and marketed as ¾-inch boards, or were thick enough over 75 percent of their length to make shorter 1-inch boards. Rejects might find use around the mill for construction or lumber pile roofs.

[3] Telford, C. J., and L. H. Reineke, "Investigation of Energy Requirements for Inserted-Point Circular Headsaws," American Society of Mechanical Engineers, 70:11 p. 913, Nov. 1948.

Telford, C. J., "Energy Requirements of Insert-Point Circular Headsaws," Southern Lumberman, 178:2235, p. 42, May 15, 1949.

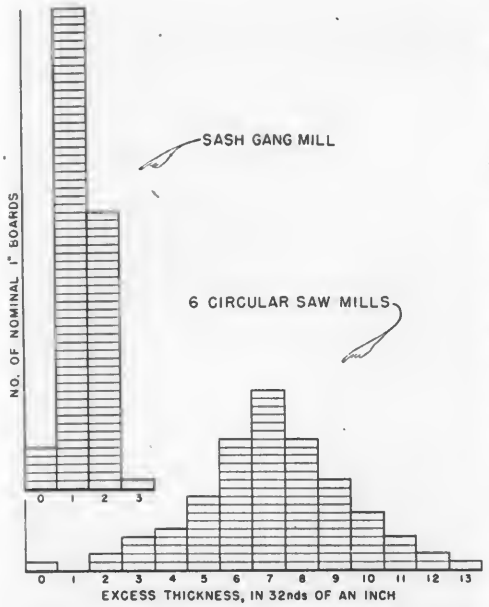

Fig. 1.—Typical thickness variations in boards cut by two types of mills. In every 100 boards produced by a sash gang mill, only 1 board exceeded the minimum required thickness by as much as $\frac{3}{32}$ inch, and 5 boards were of the exact minimum required.

and strength properties of wood and the cutting action and mechanical forces involved with various types of cutting tools.

Such studies, if attempted on commercial woodworking machinery operating at normal production rates, would require a large assortment of machines, elaborate instrumentation, and consumption of a large amount of material. The forces at the cutting edges would be obscured by other machine forces and therefore difficult to segregate. The large volume of wood handled through modern machines would make it impractical to classify the test material by characteristics such as specific gravity, toughness, hardness, growth rate, or other properties, so that the changes in forces caused by differences in the material would be submerged in an over-all average, not particularly useful because tool limitations are normally imposed by the extremes.

Tests on commercial machinery in full production naturally are a desirable and necessary part of a thorough investigation, but the profitable, effective range of such tests should be predetermined by quicker, less costly tests to weed out unprofitable lines of research and focus attention on the critical range of critical factors.

Research Basis

All machine cutting of wood can be considered as a more or less rapid repetition of a cutting cycle. With headsaws and revolving cutterheads, the cut made by one tooth or knife constitutes the cycle; with some cross-cutting saws the sequence of one group of left-hand and right-hand side-cutting and raker teeth makes the cycle; in boring or lathe work, one revolution of the drill, or one turn of the stock or veneer bolt becomes the unit cycle. A study of the unit cutting cycle should, therefore, disclose a typical pattern that is repeated in succeeding cycles.

With a full understanding of the action during one cycle, the aggregate effect of numerous repetitions is largely a matter of multiplication. Under some operating conditions, however, one cycle may affect succeeding cycles, as in saw dodging. Operational factors, such as the tool temperatures attained under continuous cutting, may affect the pattern of cutting action somewhat. The effect of repetition, however, is more readily analyzed if the independent cycle is known. This fact, plus the reduction of experimental error by accurate knowledge and control of the small amount of test material needed, makes the single-cycle approach very attractive.

Research Equipment

The method to be chosen for studying the action during single cuts or sequences had to combine sensitivity and accuracy with ready adaptability to a wide range of operating conditions, including speed, feed, cutting radius, tool and material positions, tool forms, wood species, grain direction, hardness, and other characteristics.

These requirements for a testing machine or dynamometer seemed most likely to be met by utilizing the principle of the pendulum. If a frictionless pendulum is released from a given height, it will swing to that same height on the opposite side. This free-swing height will be reduced if the swing is obstructed, as by placing a piece of wood in the path of a cutting tool attached to the pendulum. The difference be-

tween free-swing height and obstructed-swing height represents the energy absorbed from the pendulum by the obstruction. The mathematical, structural, and operating simplicity of the pendulum made it the logical choice, and design of the testing equipment was accordingly based on this principle.

The completed dynamometer is shown in Fig. 2. Essentially, the final design incorporates a pair of slanting end posts supporting an arch, from the center of which hang two thin-wall tubular pendulums, large in diameter to prevent torque deflections, hollow to receive weights adjustable in size and position to vary the energy or velocity. A tool holder is mounted on one pendulum, and a specimen holder, with micrometer feed device, on the other. The bearing shaft of each pendulum extends beyond the outer hearing and supports a two-step drum (fig. 3), the smaller one being very narrow and serving, with the wire-supported weight, as a calibrating drum, whereas the larger drum is wide enough to carry a strip of electrosensitive recording paper 10 inches wide. A set of styluses, carried by a chain driven at constant speed, moves along a straight line parallel to the pendulum shaft.

Fig. 2. — Pendulum dynamometer developed for cutting tests. Tool holder is mounted on right-hand pendulum and specimen holder on the left. Motor drives roller chains that carry recording styluses across drums at constant speed. Tape attached to each drum shows maximum angle reached by pendulum on its forward cutting swing.

Fig. 3.—Recording and calibrating drum of dynamometer, with calibrating weight suspended by wire around grooved inner end of drum. Control knobs on panel are for adjustment of voltage passed through electrosensitive recording paper by styluses carried by motor-driven chain.

Rotation of the drum under the stylus produces a trace showing the angular position of the pendulum in relation to time. This trace is sinusoidal when the pendulum swings freely. When 60-cycle alternating current is passed through the stylus, the trace is interrupted 120 times per second, producing dashes of a length proportional to velocity. Thus, velocities shown by the slope of the trace can be checked by time measurements, or the duration of a specific portion of the trace can be determined by count of the breaks in the trace. By this graph, changes in velocity in different portions of the sample, such as knots or areas of distorted grain, can be measured. When a complete record of the test is not needed, a tape graduated in degrees is attached at one end to the drum and passes through a fixed index that holds the tape at the point of maximum swing.

Operation of Test Equipment

Calibration of the machine, performance of the test, and calculation of the energy consumed in the test are in reality simple operations. The wood specimen to be used (up to 2 inches in thickness) is clamped in the specimen holder, varying the position of the holder or the direction of the grain in the specimen to permit the cutting tool to cut at the desired angle to the grain. The tool (a saw tooth or set of teeth, a straight or formed shaper blade, or other cutting edge) is placed in the tool holder in position to cut as desired, either on an inside radius as in sawing, an outside radius as in rotary veneer cutting, or in a plane as in slicing or stationary-blade planing. Both holders are clamped to their pendulum columns at positions that give the required cutting radius, but with the specimen retracted enough to be cleared by the tool. Extra weights, if needed, are placed within the columns at the desired distance from the center of rotation. The tool-carrying pendulum is raised to the desired height, and the slack in the maximum-swing tape is taken out by pulling the tape through the index. The pendulum is then released, rotation of the attached drum drawing the tape through the index until the maximum height is reached at the completion of the forward swing. The tape, which remains in position during the back swing, indicates the angle of free swing corresponding to the initial swing.

For calibration, the pendulum is again raised to the starting position and a calibration weight of 5 or 10 pounds is suspended from a steel piano wire fastened in the groove of the narrow calibration drum so that the weight is on the side away from the pendulum end and will be lifted as the pendulum swings forward.[4] After setting the maximum-angle tape and reading the initial angle (α), the pendulum is released. The maximum angle reached, (β), will be less than that in the free swing because of retardation due to the energy absorbed in lifting the calibration weight. The energy absorbed is the calibration weight (w) multiplied by the circumference (C) of the calibration drum which is multiplied in turn by the portion of a complete revolution the total swing of the pendulum represents, or

$$\text{Calibration weight energy} = w \times C \times \frac{\alpha + \beta}{360}$$

In Fig. 4, the simple pendulum released from position A has swung to a slightly lower position B on the other side because of slight bearing friction and air resistance. The energy at the bottom of the forward swing is sufficient to raise the pendulum weight w to a height h. In foot-pounds this energy equals h (in feet) times w (in pounds). Height h is readily computed as 1 minus the cosine of the angle β, times L, the pendulum length. (When angles above the horizontal are involved, as in pendulum position C, h is similarly $[1 - \cos (180 - \beta_c)]$ L, if $\cos (180 - \beta_c)$ is considered negative and subtracted algebraically.) The length L would be difficult to determine for the many combinations of weights and positions of the actual pendulum used, but need not be known. Since $h = L(1 - \cos \beta)$, energy equals $wL(1 - \cos \beta)$. The term wL is constant for a given setup. In the free swing and calibration swing

$$\frac{\text{Pendulum energy}}{\text{Pendulum energy} - \text{calibration weight energy}} = \frac{w\,L(1 - \cos \beta_1)}{w\,L(1 - \cos \beta_2)}$$

where β_1 is the free-swing maximum angle and β_2 is the maximum angle with the calibration weight. Clearing and transposing, this equation becomes

$$\text{Pendulum energy} = (\text{Pendulum energy} - \text{calibration weight energy}) \frac{(1 - \cos \beta_1)}{(1 - \cos \beta_2)}$$

For a given initial angle and pendulum setup,

$$\frac{\text{Pendulum energy} - \text{calibration weight energy}}{(1 - \cos \beta_2)}$$

is constant, and can be denoted by k, hence, for any terminal angle β, the pendulum energy is $k(1 - \cos \beta)$.

The calibration for the specimen-bearing pendulum can be made in the same way if it is to be used in either a free-hanging or a counter-swinging fashion, but need not be made if the pendulum is locked. Recalibration is necessary only if the weight distribution of the pendulum is changed.

[4] If the calibration weight is suspended on the opposite side of the drum, it will add to the energy of the pendulum. Either method is acceptable.

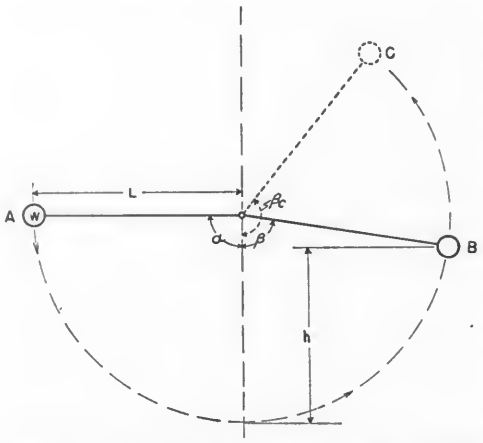

Fig. 4.—The principle of the pendulum. If the pendulum starts from *A*, its energy at the bottom of the swing is sufficient to lift its weight *W* to terminal position *B*, equivalent to a vertical lift h.

In preparation for the actual cutting tests, the wood specimen may be precut to conform to the cutting path of the tool, or the specimen may be gradually advanced toward the tool, between swings of the tool pendulum, by the micrometer feed screw, light cuts being taken until the cut includes the full cutting arc across the entire specimen. Thus prepared, the tool pendulum is raised to its release height, the specimen is advanced the desired amount by the micrometer feed, and the maximum-angle tapes are drawn up. The tool pendulum is then released to make the cut, as shown in Fig. 5, and caught on the backswing, and locked at release height for the next cut. The maximum angles reached by both pendulums are recorded, the specimen advanced, tapes reset, and the tool pendulum released. This sequence is repeated as often as necessary to obtain the number of measurements needed for averages or comparative values that are statistically reliable.

Capacity of Test Equipment

The available ranges of test feeds, speeds, and energy input are wide. One graduation of the feed screw corresponds to a feed of 2.5 mils (0.0025 inch) and feed may range upward from this amount to a quarter inch or more. Cutting speeds can be regulated from a high of 2,500 feet per minute (without speed-raising accessories) down to the essentially static conditions resulting when the specimen pendulum is pulled slowly forward against the tool, the tool pendulum applying increasing force, due to its weight, as it approaches the horizontal. Several hundred pounds of additional weights can be used to increase the static tool pressure or its kinetic energy.

Despite the wide range in test conditions, the dynamometer free-swing values are consistent to within 1 part in 4,000. Air resistance is the major source of friction loss; bearing friction was made very low by the use of preloaded precision ball bearings on the outer ends of the shafts, and by supporting the inner end of one shaft on needle bearings within the end of the other shaft, which in turn is supported by needle bearings mounted in the frame. That bearing friction is low is shown by the fact that, with the pendulum hanging free, a single hair stretched out and pulled against a razor-sharp tool edge will cause a small deflection of the pendulum before the hair is cut through.

This high sensitivity means that all the small variations in specimens and in the action of the cutting edges will be reflected in the readings of the dynamometer. Each test series must be designed to segregate the effects of variations in the sample from the variations in cutting action. This is not difficult; it merely requires that the design of the experiment be carefully worked out.

Scope of Information

The first few tests with the dynamometer showed that information aplenty could be had —and would be needed—for a full understand-

Fig. 5.—Stroboscopic type of photo of single insert-type sawtooth, carried by the tool-holding pendulum, swinging into wood sample mounted in the specimen holder on the other pendulum.

ing of the cutting action of even one type of tool. Because of the importance of saws to the forest products industries, the swaged sawtooth was chosen as the first tool for study.

The action of cutting tools is dependent to some extent on the keenness of the cutting edge. Initial sharpness may vary widely, and dulling begins as soon as the tool goes into use. A measure of sharpness obviously was needed to permit separation of the effects of keenness from the effects of other variables, such as cutter form and speed, rate of feed, and resistance of the wood. A uniform material that would not injure a fine edge might be used to measure sharpness in terms of the energy required to cut a unit area of the material.

A readily available material, uniform and reproducible, is 50–50 solder. A bar of this solder was tested as a sharpness indicator with good results, after early irregularities were cleared up. The first tests of energy consumed in cutting the solder, in relation to thickness of chip (feed rate), resulted in a more or less straight-line graph, but with far greater variation of individual values than expected. The feed mechanism was suspected of irregularities, and so a micrometer was used on the solder chips after uncurling them. Measured thicknesses were quite different from the intended feed rates, but when energy consumed was plotted over measured thickness the resulting graph was less linear and no better defined than before.

Critical examination of the solder chips showed that they were much shorter than the length of the cut area on the solder bar. This shortening became more noticeable as feed rate increased; obviously, the solder tended to cold-flow as a result of pressure by the sawtooth, and this flow thickened the chips, since expansion in width was prevented by adjacent stock. With this knowledge, it was evident that chip weight was necessary to check or determine feed rate. Variation in feed was then traced to difficulties in clamping the narrow, taper-sided, embossed-top solder bar. By plotting energy in relation to weight of chip, the variations in feed from clamping irregularities were neutralized, and the graph relating energy consumption to chip weight was a perfectly straight line of positive slope, extremely well-defined, with a correlation coefficient of 0.99754 $\pm$ 0.0024. Unhappily, however, the line passed above the origin, thus showing some energy consumption at zero feed and suggesting, at the time, some experimental failure.

The insert-type sawtooth used with the solder tests had been lapped and polished to a mirror finish (Fig. 6), to achieve an edge of maximum sharpness. Such keenness would be impractical in ordinary usage, but served as a reproducible starting point for studying the progression of dulling. This extremely sharp tooth was then used to cut dry sugar maple across the end grain, with a metered feed increasing from 2.5 mils (0.0025 inch) to 100 mils (0.100 inch). Since wood could not be expected to cold-flow under cutting pressure, micrometer measurements of chip thickness were made in preference to taking chip weight as a check on uniformity of feed.

Measured thicknesses for the various feed rates used were very consistent from cut to cut,

Fig. 6.—An insert-type sawtooth sharpened to a mirror finish reflects the lines and fibers of graph paper on which it lies. The actual cutting edge is invisible, but lies along the central vertical line at the points of the inverted V's in the horizontal lines.

but did not tally exactly with the metered or feed-screw values, always exceeding them. To locate the cause, the excess in thickness was plotted over metered feed (Fig. 7), in which the excess in thickness is practically a uniform half mil for feeds up to 15 mils, and 4.5 mils for feeds over 25 mils, up to 30 mils, the maximum feed at which the chip held together well enough to measure. The total depth of cut measured on the stock checked with the sum of all the metered feeds, thus verifying the feed-screw accuracy but posing the question of why the separate chips should measure more than the feed rate. For the feeds of 15 mils or under, the very slight excess could be attributed to a slight roughening of the cut surfaces, but some other factor must be responsible for the sudden and appreciable rise between the 15 and 25 mil rates. The answer was found in the process of chip breakup.

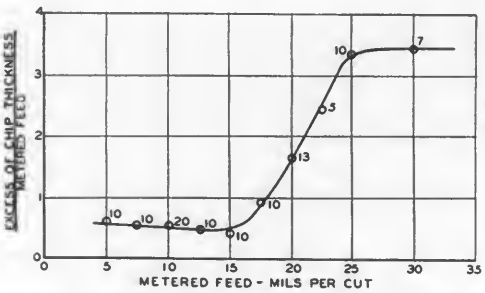

Fig. 7.—The measured thicknesses of chips cut at various feed rates exceed the metered feeds by amounts that vary with slippage of chip segments along the transverse shear lines. At feeds of less than 15 mils, excess thickness is due to surface roughness; above 30 mils the chips fall apart into sawdust as they are pried loose by the tooth face.

In Fig. 8, A is a chip 0.0025 inch thick, the thickness of a hair. It curls naturally under its own weight; it is a continuous, unbroken ribbon. Chip B is 0.0075 inch thick, and, although it is a continuous ribbon, it is somewhat stiffer than chip A and does not curl. Chip C is 0.0125 inch thick, fairly stiff, and shows some fractures and a few complete breaks due to bending by the face of the tooth or in the gullet. Chip D, 0.020 inch thick, broke completely quite a few times. The breaks become more numerous as the chip becomes thicker, until at a feed of 0.050 inch all semblance of a ribbon

Fig. 8.—Chip breakage becomes increasingly severe as feed rate increases from 2.5 mils (A) to 50 mils (E).

is lost and the chip comes from the gullet as typical sawdust (E).

Here, in the breaking up of the ribbon, is the explanation of the excess chip thickness. As the chip becomes too thick to bend over the tooth face, it tends to shear along the grain in planes that are crosswise to the direction of cut. At the minimum thickness at which these shear planes develop, the adjacent pieces are not permanently displaced, but as the thickness increases the front piece at a shear plane slides upward over the following piece, with partial rupture of attacked fibers. As a result, the successive partly detached pieces acquire a displaced and partially tipped position in the ribbon-like chip, as shown by the side view of a very thick chip in Fig. 9. This slippage and tilting increase the distance between the high spots on top and bottom surfaces, resulting in an apparent increase in thickness. The maximum excess thickness is reached at the point where the fibers holding the pieces together are too few or weak to hold the pieces in a more

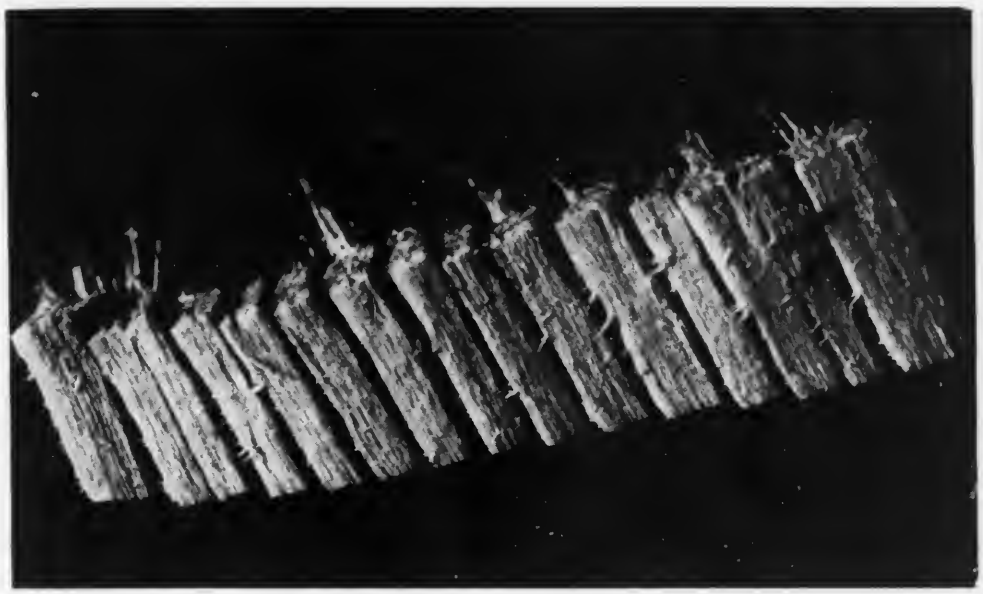

Fig. 9.—This thick chip has broken along transverse shear planes, but a few fibers continue to hold the pieces together in a tipped position.

fanned-out position. Beyond this point, fiber detachment at the shear planes becomes complete and a granulated chip results.

The process by which chips, or sawdust, are formed in ripping is vaguely suggested by the progressive change in chip as feed increases. Because of the high speed at which a saw tooth performs its duties, the details of its action are invisible.

Seemingly, the action is complex, but the complexity is that which results when several actions occur in unison or in quick succession. When the actions are taken separately, each one is merely the equivalent of a common, everyday kind of manual operation.

There are four principal actions working in the kerf in perfect coordination, each doing one of the four parts of the job. In the first, work is exerted to sever the fibers along the bottom of the chip-to-be with a very thin cutting edge. In the second step, the severed chip is pried loose from the sides of the cut, shearing the side fibers and incidentally meeting resistance from cross grain along the near side. In the third, the loosened chip is broken into small bits, so that, in the last action, the pieces of broken chip can be removed from the tight-fitting kerf.

At maximum feed rates, especially in dense or frozen wood, these four sawing actions may run into trouble. The cutting edge may dull quickly. In prying the chip loose the tool may bend, or even break off. The thick chip of dense wood will resist breakup, strongly, and may cause excessive friction and abrasion on some part of the tooth. As the broken-up chip is pulled ahead by the gullet, the resistance to chip removal places a stress on the tooth, a stress that is released—and released abruptly—at the instant the tooth and sawdust leave the kerf.

These four actions provide all the energy required to make the saw cut—including some energy in the form of heat resulting from internal friction in the wood or friction between the stock and the tool or sawdust. The division of this labor between the four actions is not always equitable. The job of fiber severing is monotonously regular regardless of feed rate, because, whether the chip be thick or thin, the same number of fibers must be severed at a constant energy input, at the level A in Fig. 10, if the cutting tool is unusually sharp, or at some higher lever B if duller. The other action of this coordinated team work hard or take it easy,

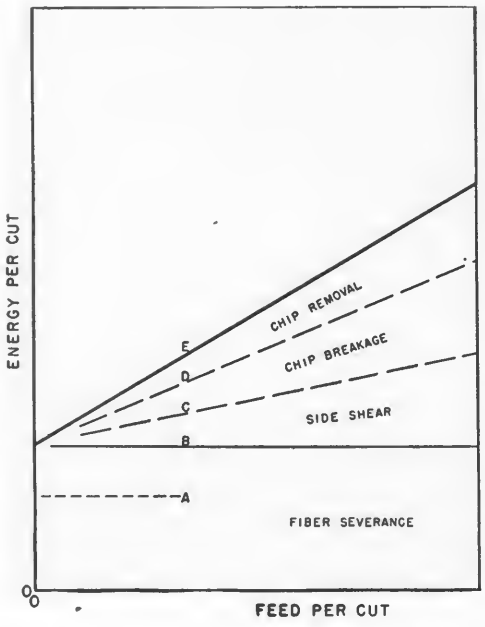

Fig. 10.—Generalized relation of total energy used in sawing (Curve E) to feed rate. Distribution of energy between the four steps indicated by Curves B, C, and D for a somewhat dull sawtooth. Resharpening reduces fiber severance, lowering curves to position A.

depending on the feed rate. When the feed is slow, the chip is thin and easily pried loose, broken up and cleaned out of the kerf. When the feed doubles, the chip is twice as thick and twice as hard to pry loose, break up, and clean out.

The energy per cut expended in prying the chip loose is added to the severance energy curve B to give curve C. Likewise, the energy in breaking up the chip, when added to curve C, gives curve D, and finally, the addition of the clean-out energy to curve D completes the summation with curve E.

The proportionment of total energy between the four actions is contingent on many factors. Besides tool sharpness, fiber severance energy will vary with moisture content, species, hardness or density, and strength of the wood. The shear strength that resists breaking the chip loose varies with species and moisture content, and the resistance will also vary with direction of grain. The energy expended in breaking up the chip will vary with shear strength of the species, moisture content, and frequency of breaks across the chip, this latter varying inversely with hook angle. Finally, the energy for chip removal will depend on the roughness of the kerf walls, the hardness of the wood, and the amount of deformation and cross grain in the wood that may cause the chips to bind in the kerf.

The numerous combinations of conditions possible will result in variation of the slope and general elevation of curve E of Fig. 10, which indicates the general relationship between total energy and feed per tooth. This curve crosses the zero feed line at a positive value, which may be low if the cutting edge is sharp (curve A), or higher as the cutting edge dulls (curve B), the series of curves moving bodily upward since the prying, breaking, and clean-out energies are independent of fiber severance energy. The zero-feed value of the total-energy curve E thus indicates initial sharpness and changes in sharpness, and in the tests with solder, the graph that 'unhappily passed above the origin' actually was indicating the force required to sever the solder, as distinguished from the energy required to free, curl, and deform the chip.

The effect of sharpness and feed per tooth on total energy per inch of saw line can be deduced from curves A, B, and E, of Fig. 10. Excluding fiber severance, the energy per cut for a given feed rate is curve E minus curve B. If this difference at various feed rates is multiplied by the number of cuts per inch, horizontal curve A of Fig. 11 can be plotted, showing that the three phases of the operation involved are a constant for a unit length of saw line (or unit area of sawed face), even though the work per cut varies. Since fiber-severance energy is constant for each cut, regardless of feed rate, the severance energy per inch of saw line is the number of cuts per inch (1 divided by feed rate) multiplied by the severance energy per cut shown by curve B of Fig. 10. By adding the severance energy per inch of saw line at different feed rates to curve A of Fig. 11, total-energy curve B can be plotted, showing a rapid decrease as the feed per tooth increases. By sharpening the tooth to the sharpness indicated by curve A of Fig. 10, curve B of Fig. 11 would be lowered to that of curve C.

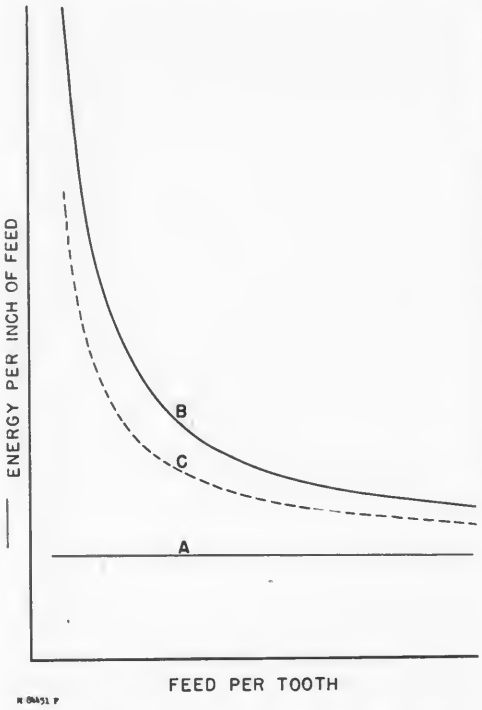

Fig. 11.—Chip loosening, break-up, and removal require a uniform amount of energy per inch of sawline (A), but fiber severance raises the total energy required per inch of sawline (B) to high values at slow feeds because more cuts per inch are made. Sharper teeth will reduce the total energy to (C), but the finer feeds will still require the greater energy.

It is quite obvious from curves B and C of Fig. 11 that a heavy cut per tooth is desirable to do the most sawing with whatever power is available. From the standpoint of power alone, sharpness is of little importance in heavy cuts, but it plays the major role when feed rates are light.

Exploitation of the power savings of heavy feeds is, of course, subject to limitation by gullet capacity and the possible overheating of the saw, if not water-cooled. Lack of sharpness when making heavy cuts cannot be ignored, because of resultant overheating and inaccuracies in cutting.

The four-way breakdown of energy distribution in a cut actually is not restricted at all times to the material that forms each separate chip. Some of the earlier dynamometer tests showed practically identical readings for successive equal cuts, yet other tests resulted in wide variation in readings. A peculiarity noticed was that the varying readings did not tend to center around an average value. Instead, close inspection revealed that the readings consisted of two sets of values, one high and the other low. When these readings were plotted in the sequence in which they were obtained, the resulting graph showed an alternation from high to low to high, and so on, as shown at A in Fig. 12. These alternating series of readings usually occurred with heavy feeds, and it was suspected that tooth dullness would cause the tooth to tend to ride up over the wood and take a thin cut, followed by an extra-heavy cut because the tooth could not ride over the wood and had to take its ordained cut plus that left over from the preceding thin cut.

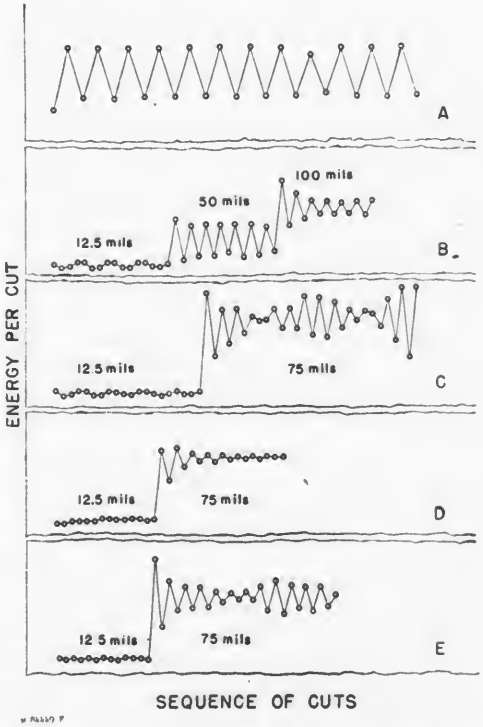

Fig. 12.—The cut made by one sawtooth may have an influence on the amount of energy required by the following tooth. High and low energies may alternate uniformly (curve *A*), or may follow several cyclical patterns (curves *B* to *E*), depending on the kind and condition of wood, tooth form and sharpness, and feed rate.

To test this theory, a factory-fresh tooth was used to make cuts at two feed rates, one light and one heavy, then sharpened to a mirror finish and used to make a similar series of cuts. With the light feed rates, the dynamometer readings were very uniform for the sharpened tooth, but alternated between high and low values for the factory-fresh tooth, confirming the theory thus far. But, surprisingly, when the heavy-feed values were plotted, the situation was reversed; the sharp tooth gave the alternating high and low values; the unsharpened tooth gave the uniform values.

The correct explanation for the alternation of energy consumption values was eventually traced to a distribution of the saw-tooth energy to parts of the wood outside of the immediate cutting zone represented by the chip. The face of the tooth acts as a wedge to shear the chip from the sides of the kerf, which is desirable, and at the same time it causes thick chips to shear crosswise of the cut, which is undesirable from an energy-consuming standpoint but necessary to permit the chips to enter and fill the gullet.

All the force exerted on the chip by the face of the tooth is not, however, applied wholly in the direction of the chip shear planes, (direction A, Fig. 13). Part is exerted in the direction B (Fig. 13), thereby putting a compressive force on the end of the chip in the vicinity of the cutting edge. The area of arrows suggests the general area that might be subjected to compression in this way. If great enough, this pressure may cause the wood to split at or a trifle ahead of the cutting edge, in the vertical direction, as at C, or along the sides of the chip above and below the cutting line, as at D in the top view. The splitting along the side causes a rough surface on the board. The splitting beyond the cutting line consumes extra energy on this cut, and the dynamometer so indicates. If the next cut occurs along the line E in Fig. 13, much of the chip break-up and side-loosening has already been done by the preceding cut, reducing the dynamometer measurement by the amount of energy previously expended on the chip. On the next cut, at F in Fig. 13, the conditions of the first cut are repeated and extra energy is expended in again producing the split condition of the second cut.

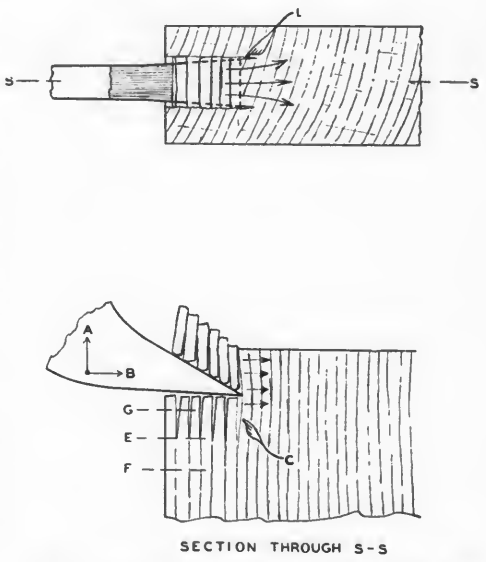

Fig. 13.—Force applied to wood by sloping front or face of sawtooth has radially acting component A, which removes the chip, and tangentially acting component B, which produces the pressure indicated by arrows in both top and side views. This pressure may produce small splits (D) along the kerf walls, slightly ahead of the cutting edge, but more severe splits (C) may extend as much as ¼ inch ahead of sawtooth cutting path. The energy required by the following tooth depends on whether cutting line is at E, F, or G.

The exact repetition of high and low energy values will result when the depth of the advance splitting equals the depth of the next cut. If the following cut occurs at E of Fig. 13, the pre-split portion will be cut off without causing splitting beyond the cutting line, thus leaving the wood for the third cut in the same condition as that for the first. If the second cut is at F, the tooth will be cutting in unsplit wood and will cause pre-splitting in the same manner as the first cut. After the first cut, the energy consumed will be uniform. If the second cutting line occurs at G, the energy consumed will be low because of the advance splitting, and these splits may or may not be lengthened by the second cut. The energy for successive cuts under these conditions may vary in a systematic manner, ranging from a uniform sinusoidal wave form (Fig. 12, B and C, 12.5 mil feed) through a modulated wave form (Fig. 12, C and E, 75 mil feed) to a damped wave form (Fig. 12, D, 75 mil feed). These sequences of

energy consumption per cut at various feed rates are not unusual, nor is the reduced variation at a heavier feed, shown at B (Fig. 12) for the 50 and 100 mil feed rates. It is possible that this variability in load on successive teeth may start the vibrations that cause washboarding, but no tests have been made to verify this conjecture.

The splitting at the bottom and sides of the cut resulting from tooth pressure on the chips raises the question of how that pressure is distributed over the tooth face. To find out, teeth were coated with blue layout lacquer. This coating wore off at the high-pressure areas during test cuts, leaving a pattern of bare steel, as shown in Fig. 14 for light feeds. This pattern is typical for swaged teeth, the only variation being in the width of the bare area adjacent to the cutting edge. For heavy feeds, the pressure area might widen back to the broken line indicated by the arrow, with no appreciable widening of the side areas.

The lack of wear or pressure on the central part of the tooth face is sometimes shown by crosswise curvature of the chip, showing that it has bowed out over the center of the tooth due to tooth pressure and the shear and frictional resistance of the sides of the cut. This bowing of the chip causes higher pressures on the walls of the cut, and requires additional energy. This can be shown by cutting narrow strips of wood that are various fractions of the width of the tooth; when energy consumed is plotted over width of cut, a sloping straight line is obtained. By next varying the portion of the tooth used, but having one corner cutting, a second graph can be developed parallel to but somewhat higher than the first. This constant increase is due to side shear along the working side of the tooth. If the tooth is cutting full width, with both sides working, another increase equal to the first could be expected. Actually, an increase is obtained, but it is considerably greater than that which would be expected from the additional side shear, indicating that the chip fits tightly in the kerf, and is possibly arched, requiring considerable energy to move.

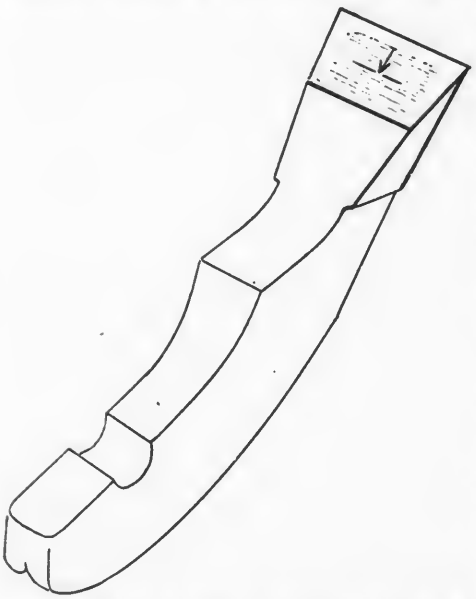

Fig. 14.—How a swage-set sawtooth wears. Shaded area on tooth face indicates test coating not worn off during use under light feed conditions. Under heavy feed conditions, the boundary of coating that parallels the cutting edge recedes to a new position, indicated by the arrow.

Can Saws Be Improved?

With complete knowledge of the behavior of wood during any type of cutting and of the mechanical and thermal stresses placed on cutting tools, it should be possible to devise a saw that would incorporate the most desirable features of operating conditions, saw materials, and saw design to the highest degree for a given type of sawing operation. Any attempt to design the ultimate saw on the basis of present knowledge would be premature, but certain facts already established might lead to some improvement.

Duo-Kerf Rip Saw

The action of the chip during formation and removal from the saw kerf offers an important lead to improvement. In breaking the sides of the chip free from the walls of the cut, sloping grain will cause the shear plane to run into the stock on one side of the cut, causing some fibers to buckle and break off or be torn out of the kerf surfaces. This tearing makes the surface appreciably rougher, requiring heavier dressing later to produce a smooth board. The tight fit of the chip between the rough kerf walls requires power to remove the chip from the kerf. One modification of the sawing action can get rid of most of these two objectionable chip

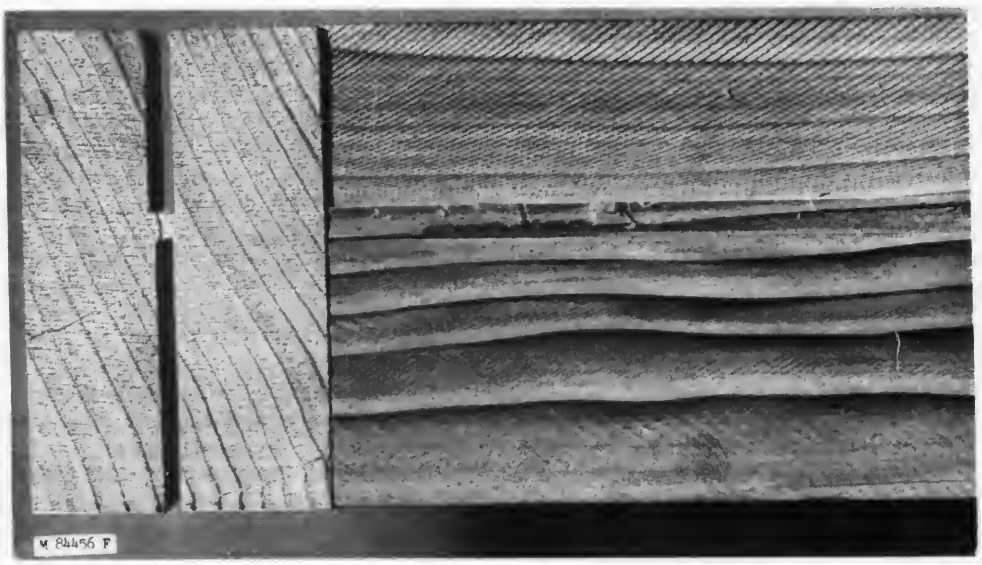

Fig. 15.—Comparison of cutting by conventional and Duo–Kerf circular sawteeth, lower surface and kerf produced by Duo–Kerf bench saw; upper surface and kerf by a conventional swaged-tooth saw of same gage and diameter.

actions. When this modification was applied to a 14-inch, 13-gage bench saw, the smooth surface and thin kerf shown by the lower half of the specimen in Fig. 15 resulted. The upper half was cut with a standard saw of the same diameter and gage.

The modification is simple. All that is necessary is to widen the initial kerf as soon as possible after it is started, in order to permit free movement of the chip after release and to provide a zone into which sloping grain can run without extending into the uncut fibers of the stock. Now, at first glance, "kerf widening" does not seem to conform with a desire to reduce scrap, but the term is used only in a relative sense. The "widened" kerf need never be wider than that of any saw that would be replaced; in general, it will be appreciably less. Obviously, to permit widening the initial kerf without increasing over-all kerf requirements, the initial kerf must be thin.

The application of the double or "Duo–Kerf" system developed at the Laboratory to a circular saw is shown in generalized form for a swage-set saw in the lower part of Fig. 16. Narrow "chipper" teeth alternate with "side-dresser" teeth that are wider and lower. The chipper tooth can be an ordinary swaged tooth, with very little set, and may be thinner than the saw plate, as suggested by the broken-line face view. The side-dresser tooth is wider than the thickness of the saw plate by the amount of side clearance required, which is less than usual because of kerf smoothness. The side-dresser tooth preferably has parallel sides and a concave face, although a flat face may be used. When the radius (r, Fig. 16) of this face equals the face width k_t, the angle at the cutting edges will be 60°; a smaller radius will give a sharper edge. The drop (d, Fig. 16) of the side dresser should be slightly, but only slightly, more than the maximum feed per chipper tooth, and the length of the side-dresser edges and the thinned portion of the chipper tooth must be equal to or more than d. The hook angle of the side dresser may vary from any reasonable positive hook to as much as 30° negative hook without change in power consumption. Beyond this limit the fibers are not completely detached by the side dressers. As a result, these partly detached fibers restrict the movement of the chipper-tooth chips, and add to the sawdust to be carried out by the chipper teeth.

The volume of sawdust removed by each type of tooth will depend on the two kerf widths used. Equal tooth spacing and gullet profile

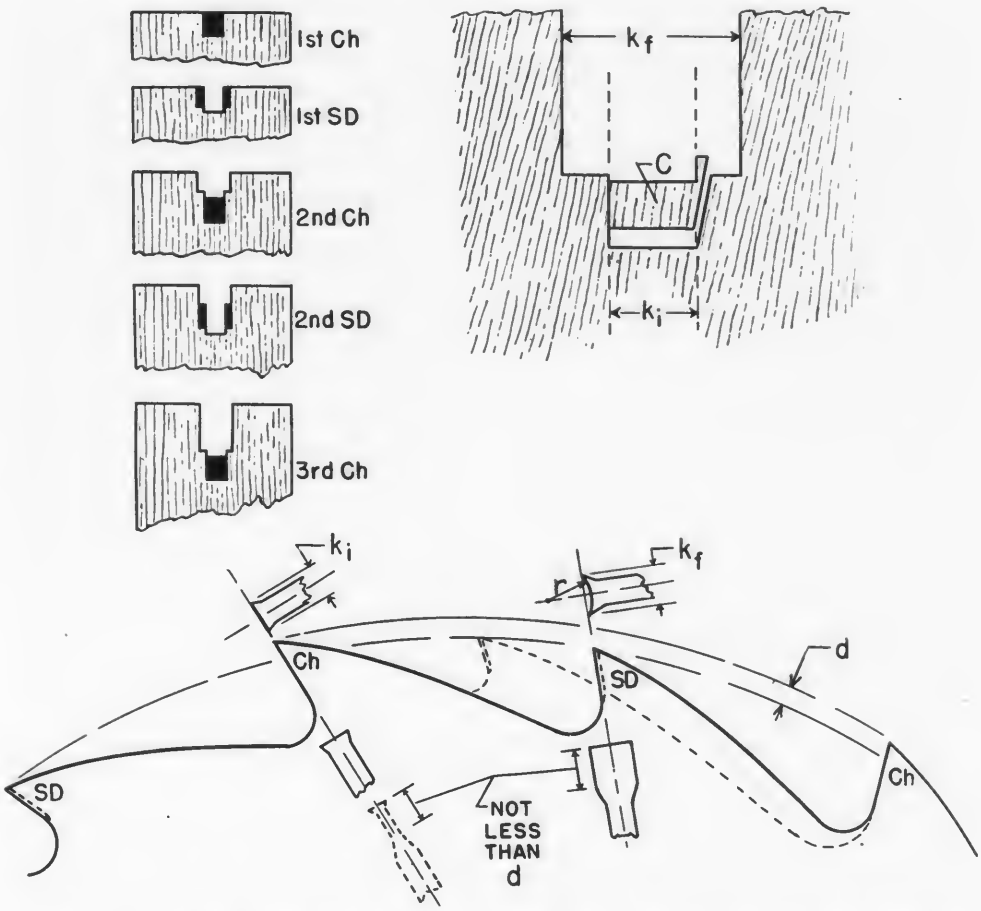

Fig. 16.—Design and cutting action of Duo–Kerf ripsaw. Chipper teeth (Ch) and side-dresser teeth (SD) may have like or unlike gullets, as indicated by solid and broken-line profiles in lower sketch. Side-dresser teeth have parallel sides and concave face, and are lower than chipper teeth by d, which is related to feed rate. Upper left, material removed in sequence of cutting actions by chipper and side-dresser teeth. Upper right, chipper-tooth chip lifted partly from initial kerf (k_i) after being sheared from kerf walls in wood with sloping grain. Note that run-out of grain at right side of chip ended in bottom of final kerf (k_f) instead of tearing into kerf wall.

area may be used, but for greatest efficiency they should be suitably adjusted, as indicated by the broken-line profile shown. Initial kerfs ranging from about 90 percent down to 60 percent of the final kerf have been used. For a ratio of 80 percent, the chipper teeth remove 80 percent of the sawdust and the side dressers remove the remaining 20 percent; therefore, the chipper-tooth gullet should have a profile area 80/20, or four times, the side-dresser gullet profile area.

The sequence of chip removal presented in Fig. 16 shows in solid black the portions of kerf that are removed by successive teeth. The first chipper tooth starts the cut with a chip k_i wide. Next, the first side-dresser tooth cuts material from both sides of the kerf to a width of k_f, and to a depth slightly short of the bottom of the first chipper-tooth cut. Following this kerf widening, the second chipper tooth advances the narrow kerf, ejecting the sawdust into the widened kerf behind it. The second

side-dresser tooth then widens most of this new chipper kerf along with the remnant left by the first side-dresser, preparing the kerf for easy removal of the chip produced by the third chipper tooth.

When the cutting direction is not parallel to the fiber direction, one of the sheared sides of the chipper-tooth chip will tend to run into the stock, but, as shown in the upper right sketch of Fig. 16, the shear plane forming the right side of the newly cut chip, *C*, runs out in the bottom of the wider kerf instead of tearing into the kerf surface, thus avoiding unnecessary power consumption and surface marring.

Other Applications of Duo–Kerf

Application of Duo–Kerf principles is not limited to solid-tooth circular saws. Inserted-tooth circular saws may be adapted to Duo–Kerf operation in several ways. Simplest, though least effective in power saving or surface improvement, would be the use of standard full-length (new) teeth of, say, 1/4-inch width in alternate sockets, and of $\frac{5}{16}$-inch standard teeth shortened as much as possible, in the remaining sockets. The normal rough surface would be obtained, but better surfaces would be obtained by converting the short teeth to the side-dresser form. It would not be difficult, of course, to manufacture properly proportioned insert bits in the two styles needed. Since side-dresser gullets need not be so large as chipper-tooth gullets, more pairs of teeth could be put into new saws by providing alternate large and small sockets, the smaller ones being positioned nearer the saw center to give the drop (*d*, Fig. 16) required for higher feed rates. This change would not, of course, be required in band saws.

As with solid-tooth circular saws, Duo–Kerf could be applied to any band saw of sufficient thickness to be swage-set. Blades too thin for swaging could be fitted by leaving the chipper teeth without set and spring-setting the side-dressers for a distance slightly greater than the drop (*d*, Fig. 16). As a possible alternative, each tooth could be made into a combined chipper and side dresser by leaving the point without set for a short distance, and setting the lower part of alternate teeth to one side and of the remaining teeth to the opposite side. The set portion of the tooth would, of course, be parallel to the width of the blade.

What Duo–Kerf Offers

Duo–Kerf, when cutting the same kerf as a conventional circular headsaw, uses 20 to 25 percent less power because of the lessened resistance to chip removal. This means that a higher production rate can be gotten without increasing the saw stresses or causing less accurate sawing. The many underpowered mills in the industry could thus benefit without change in power plant. If a mill elects to retain its present production rate, the decreased power requirements would give a more lightly stressed saw, equivalent to a stiffer saw that would cut with greater accuracy.

Any gain in accuracy increases the premium offered by the smooth surface of Duo–Kerf in reducing the dressing allowance necessary for finish lumber, thus increasing yields, decreasing drying costs, giving less work to the planer, and reducing the shavings-disposal problem. A saving of even $\frac{1}{32}$ inch in dressing allowance amounts to nearly 4 percent of 4/4 finish lumber. Even rough lumber can benefit from an improved surface through increased market acceptability. On box slats intended to carry printing, a smooth surface would eliminate the material and labor lost in dressing those slats.

These gains from Duo–Kerf can be further amplified. The smooth surface makes possible a reduction in side clearance. Reduced side clearance means less kerf, therefore less saw stress and greater saw steadiness with the same saw plate. The interlocking combination of reduced power, increased accuracy, and thinner saws can be resolved in favor of any one benefit, as individual needs dictate.

What Will Duo–Kerf Cost?

It would not be reasonable to expect large profits to start rolling in because of a switch to Duo–Kerf teeth without some stimulating investment. Money, however, is not the primary stimulant needed. The necessary stimulant—one that must be fostered by the lumber industry itself—is an acceptance of the fact that precision products result only from careful use of good tools and a determination to make the new method deliver the goods.

Bugs undoubtedly will develop in the Duo–Kerf system as practical tests are made. If special tools, materials, or methods are needed to overcome a lack, there should be no hesitation

about employing them. The secondary wood-using industries do not balk at providing tool rooms that can handle with precision the special jobs imposed by formed cutters, high-speed precision machines, glue-line abrasion, and special gluing and forming technics, because they pay off. The primary wood-using industries cannot afford to do less, for better sawing requires better tools and better care.

It is not likely, however, that Duo–Kerf will require excessive servicing or elaborate equipment. The saw that cut the surfaces shown in Fig. 14 was not fitted by an expert, and the only pieces of equipment used were a flat file, hammer, cold chisel, and hand electric grinder, plus a few carriage bolts, a dowel, and a piece of plywood for a crude jig. Simple tools, carefully used, probably will be adequate for servicing. It will be possible to slap a set of alternating new ¼-inch bits and old (short) $\frac{5}{16}$-inch bits into an inserted-tooth blade, hang the saw on a bent spindle against a dirty, burred-up collar, and still save perhaps 10 to 15 percent on power, but the full benefits of Duo–Kerf will come when it is fitted and used for precision sawing. The mounting of saws on taper-bored sleeves that are removable as a unit from tapered arbors may permit the tool room to do a really effective job of saw fitting without increasing down time of the machines. Other effective procedures can be developed by the industry.

How Industry Can Help To Develop Duo–Kerf

No one segment of the wood-using and woodworking equipment industries can make Duo–Kerf fully effective. Saw manufacturers and makers of saw-fitting machines eventually will have to provide the necessary blades, swages, and grinders. In the meantime, saw users could modify their present band and solid-tooth saws along the Duo–Kerf line with some immediate gains, which will increase as gullets are gradually altered to the desired proportions. Users of inserted-tooth saws may, if their feed rates are not too high, use standard inserted-tooth bits suitably modified, if they will use care in inserting and adjusting the bits and holders. Redesigned bits could be provided readily, but gullet changes, such as alternation of No. 4 and No. 2½ styles, would call for factory alteration of existing saws or incorporation in new saws. Bench saws would, of course, be the most readily changed to Duo–Kerf.

The exact changes needed—the ratio of initial to final kerf, and the side-dresser hook angle—may have to be determined on a commercial operation basis. As stated before, the power savings are uniform over a wide range of these factors and for markedly different types of wood. Smoothness of surface, however, is somewhat dependent on the ratio of initial to final kerf for some woods, and much work remains to be done on this phase.

The Forest Products Laboratory has done the basic work needed to establish the Duo–Kerf system. Some exploratory tests on commercial-type equipment have been made, but not under conditions of sustained production. The facilities of the Laboratory are too limited, however, to fully explore the many different conditions existing in industrial use, and it is earnestly hoped that industry will apply its own resources to some of the practical problems involved.

Discussion

Mr. D. S. Smith (British Columbia Research Council): I feel that Mr. Reineke should be congratulated for a very able paper. He has made a distinct contribution by applying the scientific method to this study of cutting action in wood.

Mr. Reineke: The problem calls for work by everyone.

Mr. H. F. Jefferson (Nettleton Timber Co.): I suggest that industry get into this research.

Mr. R. T. Titus (Western Forest Industries Assn.): Do you have data on band mills in relation to miscuts, variation in sawing, etc.?

Mr. Reineke: Mr. C. J. Telford at the U. S. Forest Products Laboratory has data on band mill variations in board thickness.

Mr. C. B. Madenwald (Henry Disston & Sons, Inc.): Were teeth jointed on side? We have a saw in use for 15 years with modified teeth.

Mr. Reineke: Uniform side-dressers are necessary if maximum smoothness is desired,

but are not necessary to obtain power reduction, as on head saws. Duo-kerf has been applied to circular head saws with insert teeth. We plan to try it on bandsaws. The Disston catalogs I have seen show no equivalent of Duo-kerf, but the industry probably would like to know where and when such saws can be obtained.

Mr. R. D. Brooks (Atkins Saw Co.): I have investigated patents. The eight-tooth saw was patented in 1850 and the planer saw in 1860. Atkins developed it again 20 years ago. Better equipment in general helps to develop specific equipment. There is a need for standardizing arbor sizes. Saw manufacturers are working on these problems, but consumers must help.

Mr. Reineke: These early patents covered the combination of two or more radial cutting edges or planer teeth attached to, or integral with, a spring set saw, with alternate cutting edges disposed to cut on opposite sides of the kerf. Because each planer knife or tooth cut on one side only, only a few pairs of such teeth were used and each had relatively long cutting edges and were set very low in the saw. As a result, the initial kerf was fairly long and much of the advantage of ejecting sawdust immediately into a wider kerf was lost. Also, normal set was carried because of the long initial kerf, and the planer teeth or knives increased the kerf beyond the normal kerf for the gauge of saw used. Thus the overall kerf and the strain on the saw plate was increased, not decreased. In addition, the planer tooth shavings were not directed into a gullet, and could jam between the planer tooth bevel and opposite kerf wall, or the shavings could follow the tooth bevel and enter between the saw and kerf wall.

Lumber Research to Meet Modern Competition

Frank J. Hanrahan

Chief Engineer, National Lumber Manufacturers Association, Washington, D. C.

The trend toward decreasing lumber markets is reviewed. How other industries expanded their markets is pointed out. A solution for the lumber and wood products industry's problem is suggested.

Introduction

WE HAVE been hearing much fancy talk about research. Before getting excited about "Lumber Research to Meet Modern Competition", as good businessmen we should examine our lumber markets and their trends to determine if there is really any need to take additional steps to retain or enlarge our markets for lumber. Some of your grandfathers spent no money for research, but still were successful lumbermen. There is a good lumber market today. Everybody knows what lumber is and has been using it for almost everything for years and years. Possibly lumber is faring better in competition with other materials than is commonly realized. Nevertheless, it is a good idea to take a look at the facts. As politicians say, "Let us look at the record".

Construction Market

Our largest lumber market is construction, which, in recent years, has taken about two-thirds of our country's lumber production in one form or another. Most of this lumber goes into building construction, particularly dwellings and farm buildings. Consequently, the figures in Table 1, which are from the 1940 U. S. Census, are of interest:

Two-thirds of all residential structures contained single-family dwelling units, and one-third contained dwelling units for more than one family. Nearly one-half of all residential structures were urban and more than half the urban structures contained dwelling units for more than one family. That was the picture ten years ago.

The overall 1940 picture of more than 8 out of 10 structures of wood is not bad. However, lest we become too complacent, let us examine the figures more closely. Also, let us look at what is being built today.

It doesn't seem so long ago that we heard that 9 out of 10, instead of 8 out of 10 residential structures were wood. In this connection it is interesting to note that more than half of the residential structures of the 1940 census were more than 25 years old ten years ago. Even in 1940, although 19 out of 20 rural farm residential structures were wood, only 7 out of 10 urban structures were wood. Further, there were nearly three times as many urban dwelling units as farm units. With increased productivity and mechanical efficiency, the percentage of the total population engaged in farming has been decreasing and the percentage in other pursuits increasing. The num-

TABLE 1.—RESIDENTIAL STRUCTURES CLASSIFIED BY TYPE OF EXTERIOR MATERIAL

Material	Urban	Rural Non-Farm	Rural Farm	Total
	Percent	Percent	Percent	Percent
Wood	71.14	88.95	94.98	81.86
Brick	20.25	4.24	1.67	11.35
Stucco	6.39	3.20	.97	4.17
Other	2.22	3.61	2.38	2.62
Total	100.0	100.0	100.0	100.0
Number of Structures	13, 962, 000	7, 381, 000	7, 417, 000	28, 759, 000
Number of Family Units	21, 616, 000	8, 067, 000	7, 642, 000	37, 325, 000

ber of new dwelling units started annually in non-farm areas has jumped from 602,600 in 1940 to 1,019,000 in 1949. Dwelling construction reflects a trend toward an urban market where wood is less popular. In other words, the 1940 census figures are far less assuring than a casual glance indicates.

Let us see what is being built today. A Federal Housing Administration annual report shows that the preponderant exterior materials for new single family buildings insured in 1946 under Section 203 by FHA were:

	Percent
Wood	40.4
Stucco or Cement Block	19.1
Brick or Stone	28.7
Asbestos Shingle	9.4
Other	0.3
Shop Prefabricated Panels	2.1
Total	100.0

Comparing the 4 out of 10 of wood insured by FHA in 1949, with the 8 out of 10 of the 1940 census gives us a rude shock, especially when we consider that the single family dwelling is the lumberman's meat. Construction practices have changed.

The preceding pertains to housing. Let us look at the overall picture of the lumber market. Let us compare overall per capita consumption of lumber with non-farm dwelling units started annually, dollars spent annually for all new construction adjusted to 1939 dollars, and the population, to get some rough idea of the overall trends:

ber markets in the last 40 years, what do you think will happen in the next 40 years if lumbermen do little or nothing to reverse the trend?

A few specific examples of what is happening to lumber markets might be illuminating.

In 1909, the wood shingle production was 18,634,000 squares. In 1947, it was 3,953,000 squares, even though the number of dwelling units built nearly doubled.

In three years, from 1946 to 1949, wood caskets dropped from 1,158,000 to 996,000 units, whereas metal caskets increased from 185,000 to 301,000 units. Each wood casket uses about 60 bd .ft. of lumber, and each outside box, about 100 bd. ft.

Also, in the last three years, lumber going into boxing and crating has dropped from 17.13 percent of the total lumber consumption in 1946 to 12.91 percent in 1949.

Forty years ago, practically all desks and office equipment were of wood. Today, only 50 percent of the desks manufactured are of wood, and less than 7 percent of the filing cabinets. Yet usually executives prefer wood for their own desks when they can afford well made wood desks.

Sheathing has been an old reliable market for low-grade lumber. In the past, such lumber has been sold on the basis of its low cost. According to recent construction cost figures compiled by a government agency from its contract bids, wood wall sheathing costs twice as much in place as some competing materials. That government agency considered dropping wood wall sheathing as an alternate from its specifications because the contractors would not supply wood sheathing at the same price as substitute sheathing materials.

A recent report states that metal has taken 50 percent of the wood window market, and that there has been a substantial loss to metal

TABLE 2.—OVERALL PER CAPITA CONSUMPTION OF LUMBER AND NUMBER OF NON-FARM DWELLINGS STARTED ANNUALLY

Year	Per Capita Consumption (Bd. Ft.)	Number of Non-farm dwelling units started (Thousands)	All new Construction Adjusted to Value of 1939 dollar (Billions of dollars)	Population (Millions)
1909	477	475	?	91
1919	324	330	5.4	105
1929	274	509	9.3	122
1939	194	515	6.3	131
1949	224	1,019	9.4	149

Judging from the data, construction activity was at a high level in relation to the population in both 1909 and 1949. The 1949 population was more than one and one-half times that of 1909, but non-farm dwelling units started in 1949 were more than double those started in 1909. Yet the 1949 per capita consumption of lumber was less than one-half that in 1909. Not a pretty picture! If this happened to lum-

in wood frames, storm sash, screens, kitchen fixtures, and cabinets.

Until relatively recently, grain storage structures of all kinds were traditionally of wood. In March of this year, the Commodity Credit Corporation purchased bins totaling 85 million bushels of capacity for storing surplus grain. The contracts were awarded on the basis of cost per bushel. Only three and one-half percent of the total capacity went to wood. On the basis of three board foot per bushel of capacity, the lumber industry lost to competing materials a sale for a quarter of a billion feet of lumber on just this one government order.

Other Materials and Construction

Some other materials and constructions that are making inroads on lumber markets include: concrete and masonry slabs which eliminate wood joists and generally wood sub-floor and finish floor in both one and multi-story constructions; light and heavy metal and concrete framing; masonry wall construction; asbestos, metal, gypsum, fiberboard and plywood used as exterior and interior coverings; steel and concrete bridges on railways and highways; plastics in radio cabinets, etc.; paper and metal in the container and packaging field; metal furniture; and many others.

Comparison of Industries

Looking at the overall lumber markets and at practically every specific lumber use, with the exception of railroad ties, it appears that lumber is losing ground in comparison with other materials. Many lumber markets have disappeared entirely. Others are going rapidly. In some cases, new developments have only made a dent as yet. Expanding lumber markets are rare.

Why is lumber losing these markets? It is generally acknowledged that fundamentally wood has more desirable properties for most uses than any other material. Could the fundamental cause be that the lumber and forest products industries have done comparatively little to retain and expand their markets, whereas competitors have done much to obtain these markets? Could it be that our industry is backward in its viewpoints and consequently, backward industrially?

Upon investigation, we find that in practically every case technical advancement and development in the material and design and in reducing the cost of manufacture and use were responsible at least in part in doing the trick. Most of these markets once belonged to lumber in which there has been relatively little technical development over the years. Truly, times have changed from the horse and buggy age to the technical age.

Examination of how other industries with increasing markets went about taking the market away from lumber may hint at a solution for the lumber industry.

Aluminum is making great strides today. Over the years, aluminum manufacturing costs have been drastically reduced from those of its early years, in spite of increasing labor costs, the enormous consumption of power required in aluminum manufacture, taxes, and all the other things which lead to general high costs of our day. Technically trained men of all kinds were employed to study and reduce every element of cost and improve the products. The record indicates how successful they were. This industry not only foresaw, but was prepared for cessation of the recent war bringing a drastic reduction of orders and a greatly expanded postwar production capacity. One aluminum company alone set up a research department of more than 3,000 technically trained men of all kinds and instructed them to investigate every possible use of aluminum and to develop fully the most promising markets. Do you think the expanding postwar aluminum markets were due to the activities of these technical men, or to chance?

At every turn there is evidence of new and extended pulp and paper markets. When one considers the relative complexity of manufacture of the two products originating from the same raw material, is there not something cockeyed industrially when a stick for an all-day sucker is made from wound paper cheaper than from wood dowels? This is the case today. The pulp and paper industry has gone all out on employing many highly trained, capable technical men, and, most important, pays top wages to draw the best men. Compared with other industries, the lumber industry employs very few technical men. Could there be any relationship between these facts?

Concrete is used much more widely today than years ago. It is far more highly refined

today than years ago, thanks to extensive research and technical development. The smallest builder in the remotest point of the United States has been taught to manufacture concrete on the site. It took a lot of technical men to do that alone. Do you think the concrete and aggregate people used good business judgment in spending money on research and technical development to expand their markets?

And so it goes with other progressive industries.

Is it not significant that a recent impartial survey of the background of the presidents of the 150 largest corporations of this country revealed that those in the largest group, one out of every three presidents, is a graduate engineer? Seven percent were graduates of commerce and business colleges and business administration courses. Is it not probable that these 150 corporations are the largest in the United States for the reason that the engineer and non-engineer heads of these organizations, all of which employ many technical men, had an appreciation of the value of, and encouraged research and technical development?

Need Technical Men

It would appear that the chief reason for slow progress in the lumber industry is that enough technical men are not in the industry, and sufficient support and encouragement have not been given by top executives to those technical men who are in the industry. Only top executives can correct this situation.

Let us look at some of the more promising developments in lumber and lumber markets.

The connector system of lumber construction has saved and recovered a large market for lumber that otherwise would have gone to competing materials. This is a product of research and technical development.

Glued laminated lumber holds forth much promise and has already saved or recovered a substantial market for lumber. This also is a product of extensive research and technical development.

Composition lumber-concrete bridge decks, another product of research and technical development, appears to be recovering some of the highway bridge market. One Oregon county alone is building six bridges of this type this summer.

Stress-grades of lumber have been established. This has brought general recognition of lumber as a true engineering material, and it is widely used today as such. A substantial market for lumber was saved here by research and technical development.

Where the going is tough competitively, the most effective arguments in promoting the use of lumber are facts obtained through technical investigations.

In our own industry, we find that we have been most successful in retaining or expanding the lumber markets where technical men have played a leading part.

The cost of lumber today is a major obstacle to expanding the use of lumber in many fields because of the lower cost of competing materials. Is it any wonder that lumber costs are high when one considers how much labor is used in its manufacture? Also in its use and application?

Isn't it about time that the lumber industry call in available technical experts from every field to review thoroughly its current practices and develop labor saving, more efficient machinery and manufacturing operations, and processes with the objective of reducing costs?

Also, isn't it about time to make extensive technical studies of how well, in relation to cost, lumber serves the user in various applications and to find ways and means of lowering the cost of using lumber for various purposes?

For example, tests show that the strongest piece of lumber in a given stress-grade is several times as strong as the weakest piece in the grade. If, through technical research, some practical means of segregating the higher strength pieces could be found, the working stresses for the stronger material could be one and one-half or two times as high as those currently used. This means that when strength is a criterion, only two-thirds or one-half as much lumber would be needed to do a given job. What impact do you think this would have on construction costs?

For some uses, stiffness rather than strength of lumber is the principal criterion. If, through technical research, a practical means of segregating pieces of commercial lumber by stiffness were found, much of the lower grade material with substantial knots, etc., could be used for purposes for which it is not now deemed suit-

able. Would such better utilization of low-grade material reduce lumber construction costs?

Most competing sheathing and other covering materials are thinner than lumber and are applied in fairly large sheets both of which tend to give cost-in-place advantages over lumber on a building. Lumber is stronger than most of the competing materials. Technical developments in lumber panels along lines similar to competing materials have been made. Would it not be in order to study the suitability of other than one-inch boards for such purposes?

How large should the studs for a house be? Tests show that wood walls have many times the strength normally required. Would it not be well to investigate technically the size required and then find economical means of manufacturing and marketing the size required?

There are any number of similar unsolved problems that bear directly on lumber markets.

Other industries have found that technical men solve industries' problems when they are given sufficient support and encouragement by top management.

I hope that I do not appear critical of wood as such. As do all materials, wood has some weak points for certain uses. Certain technical modifications of the natural characteristics of wood are advantageous for certain uses. Nevertheless, the natural advantages of the material are so many and so great that there always will be some market for wood and lumber.

Research Essential

The thought which I would like to leave with you is that the extent of the future lumber market will depend primarily on the amount of attention given to research and technical development in both the production and use of lumber. This is a technical age. Is not any industry, in which the technical man does not play a very important part, automatically behind the eight-ball? And isn't it likely to stay there so long as this condition prevails? If a future healthy lumber market is to be achieved, is it not essential that research and technical development in the use of lumber be accelerated and expanded to meet modern competition?

Discussion

Mr. Donald R. Dawson (MacWilkins, Cole and Weber): Are not publicity and advertising important in increasing lumber sales?

Mr. Hanrahan: Very important! For best results, the lumber industry must continuously keep the merits of its products before prospective buyers, users, and the general public. However, in the construction and industrial fields where the bulk of our lumber is used, the cigarette or toothpaste type of advertising and publicity is not very effective. Here the soundest publicity is based on provable data and facts. A technical man is best equipped to ferret out and develop such scientific data and facts. The publicity man is best equipped to dress up or dramatize for public consumption the favorable data or facts developed by the technical man. Hence, both technical and publicity men are needed by the industry.

Mr. J. D. Snodgrass (Oregon State College): What avenues for research and product development are open to the industry?

Mr. Hanrahan: The approaches are practically unlimited. Technical personnel and facilities for assisting industry are available from lumber associations and their laboratories, federal government laboratories such as the U. S. Forest Products Laboratory, state and university laboratories, commercial laboratories, consultants and specialists of all kinds.

Employment of technical men by the individual company is likely to be the most helpful of all. This permits the technical man to study at first hand and be in constant touch with the technical problems peculiar to the specific operation. Also, there is a great mass of helpful technical data lying in various laboratories which is not getting into application for lack of technical know-how in the individual plants. Although it may take some time for a technical man to get acquainted with the company's business operations and technical problems, a technical man worth his salt will start saving his salary several times over in a relatively short time. His technical knowledge, analytical approach, and new viewpoints will pay dividends in many money-saving ideas.

Not all concerns are large enough to employ many kinds of technical men and therefore will have to concentrate on their most pressing

problem or problems. If the problem is efficiency in mill production, get an industrial or mechanical engineer. If it is a forest management problem, get a forester. If it is sales in the construction field, get a sales minded architect or civil engineer who knows the industry you are trying to sell.

Where a firm is too small to employ a full time technical man, the owner can obtain assistance by contacting technical men who specialize in the field of his problem, either as individual consultants or as a member of an organization which has a staff of consultants. Your lumber associations and state and federal institutions will be glad to advise you where you can obtain the technical assistance needed.

Where the problem is of joint interest to several firms, a producing region, or nationally, most rapid progress can be made by the pooling of efforts. Your lumber associations are so organized as to handle such joint enterprises efficiently within their own laboratories, or by arrangements with other organizations' laboratories or consultants.

Mr. Roy M. Carter (North Carolina State College): I am glad that you emphasized the need for technical men in the industry. North Carolina State is training men but there is need for practical training. How can we get industry not to expect too much? How can we get industry to hire more?

Mr. Hanrahan: With respect to your second question, it is up to the technical men and others who believe in technical men to convince the executives of the industry that hiring technical men pays dividends. Specific illustrations of contributions made by technical men measured in terms of dollars of profit are the most convincing arguments. As more technical men get into the industries and prove their worth, more will be employed. Meetings such as this focus attention on the problem and, at least to that extent, should be helpful.

With respect to your first question, the schools can provide only the basic technical training and create the right mental attitudes and viewpoints. In turn, industry must provide the technical men with the opportunity to get some practical experience before it can expect too much. Possibly the school faculty could be helpful by discussing with both the employer and the student being hired the best methods and means of further development of the student after leaving school.

In such a conference, it would be well to call the attention of the employer to the fact that, for best results, the company needs to give the new technical employee an opportunity to become familiar with the firm's overall objectives and methods of operation as well as with the detail of the work to which he is to be assigned. Otherwise the new man is not in the best position to steer his efforts with maximum effectiveness in those directions which are in accord with his employer's interests. Also, it would be well to point out that with the enormous ramifications of technical fields today no technical man can be expected to be a specialist in all technical fields. Too often, because he is a technical man, the employer expects, for example, that a chemist can serve effectively as an engineer, a forester, and in a hundred and one occupations for which he was not trained. Any such expectations are doomed to bring disappointment and dissatisfaction with the technical man. The technical man may do a credible job in many fields basically related to that field for which he was trained, but it is impossible in this technical age to provide any one man with fundamental training in the whole gamut of current technical activities.

Items which need to be brought emphatically to the attention of the student include: (1) that, although an employer may anticipate that it will take some time for the new employee to get into the swing of things, the only reason the employer is hiring the technical man is that the employer thinks he eventually will produce enough to pay his own salary and a profit in addition. No employer can operate for long at a loss; (2) that the student should immediately set about getting all the information he can which will be helpful in his future work and keep continually in the forefront of his thinking that the objective of the business is to make a profit; and, (3) that he should not hesitate to get his hands dirty, because one of the quickest and best ways of learning is by doing, whereas one of the quickest and surest methods of courting disfavor with his employer is playing at being an executive who is above doing menial work.

Mr. H. F. Jefferson (Nettleton Timber Company): To what extent do you train men in exercising imagination?

Mr. Carter: One method we use to stimulate thinking and imagination is the open book type of quiz. That is, we give the student a practical problem and let him use material from any source such as textbooks to aid him in solving the problem. He must call on his imagination for the practical details of the situation, analyze the problem and determine what controlling technical principles are involved, and then, using whatever technical data he thinks helpful, present the best practical solution he can. We also use the laboratory to advantage in stimulating his imagination.

Mr. R. M. Melrose (F. S. Harmon Manufacturing Company): Would Professor Sigurd Johnson care to discuss his technical training of college graduates for production supervision?

Prof. E. Sigurd Johnson (North Carolina State College): North Carolina State College will turn out 20 men a year trained for furniture production. With this training, they should exert important influence on the technical aspects as well as do important technical work in the industry.

Mr. Melrose: What about production jobs covered by unions? Do you have a union problem in getting technically trained men absorbed in production training work?

Mr. Johnson: This is not a problem in the Southeast.

Mr. Melrose: This is a big problem in the woodworking industry in the Northwest (and elsewhere in other industries). In industries where unions are well entrenched, all production jobs are jealously preserved for union members—usually in accordance with seniority rights. Any attempt to bring men into these positions to give them a survey of the work through actual experience is met with organized resistance. Yet the biggest gap in industrial application of research comes between the research laboratory and actual production work. The man who actually has the job of putting into action the new technical changes is the foreman; and if the foreman is not technically minded, the new developments from research will be resisted from the start. Therefore, it is incumbent on management and labor to develop training programs whereby technically trained men may be absorbed in production as potential supervisors.

Mr. Jefferson: Industry and unions are both working on this "union" problem for college graduates.

Mr. R. C. Fraunberger (Philco Corporation): In his discussion Mr. Hanrahan mentioned the replacement of lumber by plastics in radio cabinets. Also, steel has been introduced and is now used in radio cabinets. Philco has a steel television cabinet, as well as plastic and wood cabinets, in its new 1951 line.

I would appreciate having Mr. Hanrahan's ideas on how one goes about undertaking research and technical development so as to make it pay for itself.

Mr. Hanrahan: Intelligent thinking and careful planning in advance are potent ingredients of successful research and product development. Most business concerns are not institutions which are primarily interested in research for the purpose of acquiring new information as such. They look upon research and product development as a means for improving the health of their business. Consequently, before undertaking a given research project, management should make up its mind whether, if the findings are favorable, it will be willing to use or apply the research findings from the project proposed. For example, if the management of a lumber concern is not willing to extend its operations into the pulp and paper field, obviously research, no matter how interesting or promising, leading to pulp and paper applications will not pay its way because the benefits come from application of the findings. It is important that company research projects be consistent with the policy or prospective policies of the firm. The research and product development department should not be treated as a step-child. It should be considered an integral part of the business and receive the same attention from management as other departments.

Initially, a few of the most promising leads should be selected for investigation. Then, as the research progresses, the work should be reoriented periodically to take advantage of new promising leads as they develop. For best re-

sults it is essential that men who are competent in the field in which the investigation is being conducted either supervise or do the research work. Otherwise faulty or unreliable research findings may lead to many headaches such as production difficulties and costly consumer rejections when the findings are applied in production.

Further, the businessman should realize that the mass of our technical findings and advancements come from persistent, intelligent thinking and hard work—not just brainstorms—a fact to which the lives of our great inventors so eloquently testify. Consequently, periodic miracles should not be expected of any research staff. However, over a period of time, intelligent, continuous research does pay off, sometimes magnificently.

Mr. J. Alfred Hall (Pacific N. W. Forest Experiment Station): I think Mr. Hanrahan painted a picture which is too pessimistic with regard to future wood markets. There are many fields in which wood products markets have been greatly expanded — particularly where wood is going into fibre products.

Mr. Hanrahan: I agree that the pulp and paper and some other wood products groups have done an excellent job in advancing their markets through technical advancement. My previous comments were intended to apply to the lumber market only.

Mr. Fraunberger: Lumbermen have been very poor merchandisers. Grade names have not had public appeal. Such terms as Common Shop, Box, etc., have not done much to glamorize lumber and help sales. Wood substitutes have done a good merchandising job. Couldn't changes in terminology help to improve our merchandising?

Mr. Hereford Garland (Michigan College of Mining and Technology): What kind of technical men does the industry need?

Mr. F. H. Vogel (Alabama Polytechnic Institute): I would like to point out that the Utilization Division of Auburn's Forestry School has been stressing the practical aspects of education in our field. We use a text only as a skeleton background on which to build a course. Our students learn to operate and maintain all the usual machinery and equipment concerned with work in utilization, and they have to think to pass our tests. I don't believe in memorizing data; it can seldom be used from memory, anyway. What I do believe in teaching, and what we stress at Auburn, is how to connect various known fundamentals in order to solve *new* problems.

The kind of men in whom the industry is interested include those who can figure out what is *not* in the book or lecture notes, and that's what we are now striving to give you. I am sure that we are not alone in this aim in the utilization field.

Mr. Hanrahan: Mr. Jefferson has pointed out that imagination is very important. Professor Vogel has emphasized that it is essential that a technical man be able to apply his scientific knowledge to new problems in a practical way. I concur with both gentlemen. In addition to these attributes and the character qualifications always sought, I suggest that, for really technical assignments, the employer select a man who is technically trained or experienced in the particular field of endeavor to be pursued. I have seen some very unhappy experiences where a technical man who is quite competent in one field has endeavored to serve as a technical man in another field in which he was not qualified. I have in mind a case in which a very capable forester and recognized authority in his field with a doctor's degree in wood technology was assigned to and, in spite of his best efforts, fell down miserably in doing wood research and forming technical design recommendations in the field of structural engineering design. The technology of any of our major technical fields is just too vast and complicated for anyone to master thoroughly in a short time. Such ill-advised technical assignments or undertakings are not only unproductive and likely to prove costly, but the results tend to destroy the confidence of businessmen in all technical men.

FOREST PRODUCTS RESEARCH SOCIETY

Hardwood Log Grading—A Phase of Quality Control

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This paper points out that the variability of trees and the diversity of use requirements indicate the need for a realistic system of log grading. The essential requirements of such grades are outlined, as well as some of the technical difficulties involved in their formulation. A system of hardwood log grades is discussed in some detail.

Introduction

HENRY ADAMS once said that a man's education should start with his grandfather. Ideally, quality control in the wood-using industries should follow the same principle, to the end that genetics would play an active part in shaping our forest resource. Less ideally, but still to the point, our current timber crops could be subjected to silvicultural measures designed to yield superior trees. Practically however, today quality control should and can start with the mature tree. With the wide range of wood qualities in our present timber supply, quality control is largely a matter of selection. It is generally recognized that, in addition to the full quality gamut being present in many stands, the average level is rapidly lowering and the variability increasing. It is no secret that like a good man, good timber is hard to find, and in many sections this lack has created serious industrial situations. The seriousness is attested by the high prices paid for good timber, and the long distances over which it is transported. More specific are the recent National Forest Survey statistics. In the State of Mississippi, 40 percent of the saw timber stands were found to contain only timber of the poorest grade. Of the State's total, 17 billion board feet of hardwood saw timber, 11 billion or 65 percent is in third grade logs. In the Ozark section of Arkansas the situation is worse, for the first and second grade logs make up only 20 percent of the present saw timber. They comprise only 25 percent of the 7 billion board feet of saw timber growing in western Tennessee. In Vermont, one of our best northern hardwood states, about half of the logs are of the poorest grade and only 25 percent of the highest.

The importance of the timber quality deterioration over most of the East at least, has been obscured by several things. One: We have just been through a long war period when normal quality requirements and historical value relationships were dislocated. Two: Over the years, we have been gradually adjusting our use requirements downward. Three: We have been unable to obtain an adequate measure of the situation because of a lack of a generally acceptable techniques for measuring impartially and consistently, the basic quality level of our standing timber or forest yield.

How far the dropping of quality standards can or should go is problematical. Certainly, it is one way out, but perhaps not an altogether desirable one. New manufacturing and conversion techniques, new standards of value, new consumer acceptances, different costs—all these factors are involved. It is possible that the pinch of poor quality can be staved off for a period, and possibly forever. Metals, plastics, and synthetics will play their part in and have their effect on the situation. However, wood use is so vast, so habitual, so much an integral part of our economy that ultimate adjustment by substitution will be a long process, and perhaps an unnecessary one, provided proper steps are taken to use our remaining "quality wood" effectively, and to rebuild and maintain an acceptable quality level. Standard grades for forest products are essential tools for accomplishing this.

It may appear that the problem of establishing forest product quality standards is a simple one. It may be argued that we are dealing merely with pieces of wood, and that all that is required is to set up a descending scale of values for pieces with certain measurably differ-

ent specifications, let the several users pick the grades they individually can use, and that's that. In theory, the problem is as simple as that. Actually, it is one of the most complex situations facing both wood growers and users.

Background for Log Grading

To begin with, timber and log growing involves a number of curious situations, many of them lying in the psychological field. Some of them are:

1. Timber and logs are generally not bought and sold by the piece or pound over the counter. Rather they are traded, with both seller and buyer (and generally the latter) banking on knowledge or lack of knowledge on the part of one or the other to consummate a good deal. This is traditional, but creates a difficult situation to overcome.

2. The usual methods of measuring quantities are, to say the least, not precise, and often compensate, one way or the other for quality variations. If and when this occurs, it is by accident, rather than design, but it does take pressure off converters when low quality is tied closely to small size. The Doyle Rule is especially effective in this respect.

3. Although the basic quality of a piece of wood may be constant, its value is not. A piece of wood is not homogeneous. The highest quality log for example, can and generally does yield some lowest grade lumber. Market prices and demands for low grade products, particularly, can easily alter desirability of a log.

4. Timber is converted under a tempo and with facilities which all too frequently leave neither time nor space available for the task of accurately measuring quantity and quality of round products.

5. In many sections, log making is a "taken-for-granted" operation. It is generally recognized that woods supervision has been inadequate to control and woods labor uninterested in developing quality, except as accidentally involved in making quantity.

6. Operations are rarely confined to one species, and certainly involve a wide range of timber sizes. The use of quality standards would add a large number of complications to a computation system already cumbersome. These can be overcome by mechanical computation methods, but few are aware of the techniques involved.

Then, there are other more technical difficulties. Some of the most important of these are:

1. There are often conflicting use possibilities for a given piece of wood. A log, for example, may be of highest quality for factory lumber, and also be a fine veneer log. In addition, it may be useful for structural products, and certainly would make superfine dunnage. Yet the technical requirements for each of these items are different, and every log will not yield equal values in all products. Some high grade factory lumber logs will be cull for structural purposes. This leads to difficulty for

   (a) there is confusion between use classes (i.e., pieces most suitable for a given use) and grades (i.e., pieces within a use class, of different levels of value).

   (b) There is an understandable desire on the part of many for a simple 1-, 2-, or 3-line statement of a quality system, which leads to attempts to discover ultra-simple approaches, and to resistance to the logical system which is of necessity complicated. (Experience in this field, however, indicates that the complications are more apparent than real, so far as practice is concerned.)

2. There is a lack of adequate published information on factors affecting quality. First is the problem of identification; then, second, that of evaluation. Does this or that affect quality? If so, under what circumstances, and to what degree?

3. Pieces of wood (logs) of certain specifications may have a high value for a certain use. A piece of different specifications may be unmerchantable for the first use, but have an equal value for another. This over-lapping of values for different classes and grades for different end uses which precludes the development of a logical scale of descending desirability, is a cause of confusion.

4. There is an element of interchangeability between uses for certain pieces of given specifications which further complicates the matter. Some logs of one class can be used for purposes of another, but not all logs can be interchanged.

Due to market conditions, it may be desirable to make such an interchange at one time and not at another.

Guiding Principles

In view of all these, and other complicating and confusing elements in the situation, it is necessary to set forth certain arbitrary guides if a standard system is to be evolved. Such guides are:

1. The system must be related as closely as possible to current utilization practices, and must be purposely directed toward current uses.

2. An arbitrary scale of descending desirability must be formulated for products and end uses.

3. Classing or grading factors must be such that identification and evaluation can be precise and consistent.

4. Specifications for classes and grade may, but need not coincide with those required for any specific products. Specifications for such specific products, where different, should be related locally to standard grades or classes.

Specific Requirements

Having established basic requirements for a standard quality measuring system, it is now in order to become specific. For illustrative purposes, the following discussion will be directed at hardwood log utilization exclusively.

To begin with, the general requirements given above can be translated into a definite working system for hardwood as follows:

1. Sawn (and veneered) products will be given preference over others, such as pulpwood, chemical wood and fuel wood. This means a first breakdown of the available cubic volume in a tree into two parts; namely, those pieces suitable for sawn products, and those not suitable. A separating specification is required. This cannot and need not be formulated directly but obviously will be a combination of the numerous requirements of the products included. It does however, require the establishment of "floors" for the individual items.

2. Within the sawn products group, due to current practice, two groups will be set up; namely, sawlogs and sawbolts. Here again a separating specification is required. This specification actually becomes, then, the floor of the system for measuring log quality. It is realized that the poorest or lowest grade log is not a fixed thing, and that it will vary with operating and economic conditions. However, if the specifications are set on the premise of good economic conditions, the chances are that any change will cause requirements to go up substantially. When they do, the next highest standard class (or classes) can be considered the minimum. Following this idea the required specification for the poorest log is:

Any piece of a stem more than 8-inches in diameter, 8-feet in length with a sweep in inches not exceeding ½ the diameter of the small end, but with over ½ the gross volume sound and with any number of knots, holes, or rotten areas providing the diameter of none exceeds ½ the diameter of the log at point of occurrence.

3. The floor for the log group having been established, logs will be segregated into use classes set up in accordance with an arbitrary scale of descending desirability. This segregation or separation is the key to successful value subdivision, and is the basis of all grading. The authority for judgment on these use classes is the rules book of the National Hardwood Lumber Association which lists and gives specifications for most of the commonly sawed hardwood products. A study of these rules shows that there are three basic use classes, each—and this is important—with unique technical requirements, which preclude use for any other purpose when *arranged in a descending scale of desirability*. That is to say, although wood of the highest considered use may be used in some cases for lower purposes, wood in a lower class cannot be used economically, (and often technically), for a higher purpose when consideration is confined to products listed. These basic use log classes can be called factory, structural, and miscellaneous local use.

Factory Lumber

Factory lumber use is based upon producing lumber later to be recut into smaller pieces, each practically free from blemishes and imperfections. The value (grade) of such lumber is determined by specifications of the official National Hardwood Lumber Association grading rules for standard lumber. These control the yield of such defect-free pieces which can be

cut from the original board of a given grade. High grade boards are those which will yield high percentages of clear material, with individual pieces relatively large. Low grades are those which yield low percentages, generally only in the smaller sizes. The technical base for the grading is the so-called clear face cutting. This is defined as having one face absolutely free from defects and the reverse side "sound," which means free from rot, heart center, shake and wane, but with other certain defects, which do not impair the strength of the cutting. These others include sound knots, sound bird peck, stain, streak or worm holes. Products included in this factory use class are standard lumber, sill stock, step plank, cabinet ash, elm, hickory and pecan, basswood key stock, and flooring lumber.

Structural Lumber

The second (structural) class of use includes that in which pieces are to be used more or less intact for building or weight-bearing purposes. Specifications for the products are found in the construction lumber section of the National Hardwood Lumber Association rules, the tie specifications of the American Railway Association, and the standard specifications of the American Society for Testing Materials for structural wood members. These specifications, in general, control strength of piece. Knots and other defects which would reduce the strength are limited to sizes which hold impairment within satisfactory limits. In large items, the position and condition of heart is specially important. Although factory lumber grades allow for progressively more defects from the high grades to the low grades, specifications for structural items are rigid throughout with regard to the inclusion of weakening imperfections. This results in log requirements different from those for factory use. For example, often enough high-grade boards can be taken from the outside of a log with rotten, shaky interior and large but widely spaced individual log defects so that average quality of product yield may be high. Such a log might be a cull as a structural log. Among the products included in this class are ties, sound square edge, select and No. 1 dimension, No. 1 and 2 utility boards, select car stock.

Miscellaneous Local-Use Lumber

The third class of use comprises miscellaneous products either not usually covered by any standard specifications, or by rather general ones. The uses generally do not require high strength, great durability, or fine appearance. The products are of low value and are generally sold in local or restricted markets for such uses as secondary farm buildings and crating. It also includes bridge and crossing plank, sheet piling and other miscellaneous construction items. Whereas the products from the first two log classes are usually sold over a wide area through a variety of marketing channels, miscellaneous use materials are generally sold direct to the user by the producing mill.

Other Possible Use-Classes

Although the three uses discussed cover most hardwood lumber production, there are other uses which assume local importance. Interior finish is one of these and it is possible that a basic class should be developed for it. However, the present hardwood finish business is so small that this use can be included in the structural class. Finish use will assume much more significance in the softwood picture. Other important uses are for veneer (both commercial and container), cooperage, dimension and handle stock. Studies are needed to relate requirements for these items to the standard basic use classes. It is probable that they will be most closely related to the factory use for relatively short clear pieces of practically perfect wood or veneer sheets with few or widely scattered defects.

Grade Specifications

Next, for each use class as described above, as many grades as are desired can be set up to divide the included logs into a series of value groups. The usual procedure is to divide the class into three such groups (grades) representing high, medium, and low value bands. To set up such grades requires that the factors affecting quality within the class be evaluated and arranged into a set of clear-cut specifications. To be practical, the grades must meet the following requirements:

1. *They must be based upon external measurable characteristics.* In case of logs, surface and end features can be used; in case of trees,

surface features only. Possible factors would be the position of log in the tree, (at least whether it is a butt log or whether an upper log); the straightness of the log; pattern, size and character of log surface abnormalities such as knots, bumps, bulges, worm holes, cracks and breaks or changes in pattern of bark. Available on the end of logs to guide judgment would be such things as rotten, doty, stained, shaky, and insect-damagaed areas.

2. *They must "work" on relatively small quantities of logs.* With all the variations that occur in logs, it can be realized that to put each log into an exact value classification would require a long and complicated set of specifications. On the other hand, a few simple rules such as size and amount of cull might give fairly consistent average values if applied to thousands of logs. Somewhere in between is the ideal. The system should satisfy if it will give a consistent average with 25 or 50 logs.

3. *The system must be as simply and "learnable" as possible.* Many, in considering this matter would like to have the rules contained in a one, two, or three line statement. This is highly desirable, but practically impossible. On the other hand, as has been indicated above, it would be possible to build up a set of specifications which would fill a book and which could be used only by experts with long years of training. In this matter, reason must prevail. As Abe Lincoln said, "A man's legs must be long enough to reach the ground." Grading specifications must be sufficiently explicit to do the job required. It is not unreasonable to expect those engaged in the timber business to learn a somewhat complicated system. It is known that the system will not be as demanding as the various lumber grading systems.

Present Status of Log Grades

Having discussed the principles upon which a log grading system should be based, it is now in order to discuss the present status of log grades for various use classes. For the factory use class, there is a set of specifications developed by the U. S. Forest Products Laboratory after extensive studies in the various hardwood regions. These are included in the publication, available for distribution, entitled "Hardwood Log Grades for Standard Lumber" (Forest Products Laboratory Publication No. D 1737). The specifications are shown in Table 1. For the tie and timber class there are no formally published specifications; however, Table 2 gives suggested specifications suitable for use until further research has established more perfect rules. For the local use class, no grades have been developed or are suggested. It may be considered that this class is one grade which contains those logs not good enough to enter either the factory or the structural use classes, but which still meet the basic specifications for the poorest log, as defined earlier.

TABLE 1.—HARDWOOD FACTORY LUMBER LOG GRADE SPECIFICATIONS
(From Forest Products Laboratory Report D 1737)

Grading factors	Log Grade									
	F 1			F 2					F 3	
Position in tree	Butts only	Butts and uppers		Butts and uppers					Butts and uppers	
Diameter, scaling, inches	[1]13–15	16–19	20+	[2]11+		12+			8+	
Length without trim, feet	10+	10+		10+	8–9	10–11	12+		8+	
Clear cuttings on each of 3 best faces—Length, minimum, ft.	7	5	3			3			2	
Number, maximum	2	2		2			3			
Yield in face length	5/6	5/6		2/3	3/4	2/3			1/3	
Sweep allowance (maximum)—Less than 1/4 of end in sound defects, percent	15	15		30					50	
More than 1/4 of end in sound defects, percent	10	10		20					35	
Cull and sweep allowance (maximum), percent	[3]40	[3]40		[4]50					50	
Sound end defects	Special instructions available									

[1]Ash and basswood butts can be 12 in. if otherwise meeting requirements for small No. 1's.
[2]10 in. logs of all species can be No. 2 if otherwise meeting requirements for small No. 1's.
[3]Otherwise number 1 logs with 51 to 60 percent cull can be No. 2.
[4]Otherwise number 2 logs with 51 to 60 percent cull can be No. 3.

TABLE 2.—SUGGESTED SPECIFICATIONS FOR STRUCTURAL LOGS

Specifications		Log Grades T1	T2	T3
Position		Butt and upper	Butt and upper	Butt and upper
Diameter		20 in.+	11 in.+	8 in., 9 in., 10 in.
Length, without trim		12 ft.+	8 ft.	
Clear cuttings		No requirements	No requirements	
Sweep, absolute		¼ dia. small end	½ dia. small end for each 8 ft. of length.	
Sound surface defects	Single knots	Any number if dia. of collar is not over 4 in.	Any number, if no one knot has an av. collar dia. in excess of 1/3 of log diameter at point of occurrence.	
	Whorled knots	Any number if sum of knot collars does not exceed 4 in.	Any number, if sum of collar dia. does not exceed 1/3 of log dia. at point of occurrence.	
	Holes	Any number if dia. does not exceed 4 in. and if none extends over 3 in. into included timber.	Any number provided none has a dia. of over 1/3 of log dia. at point of occurrence, and none extends over 3 in. into included timber.	
Unsound surface defects		Same requirements as for sound defects, except no limit if do not extend into included timber.	Same requirement as for sound defects if they extend into included timber, no limit if they do not.	
End defects	Sound	No requirements	No requirements	
	Unsound	No vol. limit, but all must be confined to heart center.	None allowed; must be sound internally. Will admit 1 shake not more than 1/3 width of and 1 split 5 in. long (max.) in contained timber.	

How Grades Are Applied

Discussion therefore, can be confined to the process of grading factory logs and structural logs. For the former, the Laboratory studies showed that the value of the lumber produced is controlled in part by the position of the log in the tree. In general, butt logs of a given character turn out better than upper logs. Differences in size of logs are very important, especially diameter variations. Changes in length are less important in the individual logs for the highest grade product permits pieces of all lengths down to 8-feet; however, there are definite limitations on the percentages of the short lengths which may be included in large shipments of a given grade, and there is sometimes a premium on shipments containing all long lengths. So, length must be considered. Another important factor is crookedness, the immediate effect of which is to bring the center of the log (which normally contains blemished wood) nearer the surface of the log and to give an abnormal distribution of these central and other wood defects.

Other significant factors are amount of cull (rot, shake) and presence of such things as stain and worm damage. These are generally visible on the ends of the logs and can be evaluated there. But the most important factor to be considered is log defects. These are external evidences of internal blemishes in the wood. They may or may not be associated with cull. They include such things as knots, bumps, cracks, holes, limbs, wounds, and overgrown features such as limb stubs, insect holes, and bird peck. These are evaluated under the Forest Products Laboratory system by dividing the log visually into 4 lengthwise sections or faces, each representing the slab which would be cut off if the log were squared up. By applying the principles used in grading hardwood lumber, a good correlation is obtained between log surface character and lumber grade yields. Under this principle, the faces are graded, not directly by number, size, and character of defects, but by the distribution or pattern of these. This is gauged by number and size of "clear cuttings" (defect free areas) on the 3 best faces.

All of these factors (position, size, straightness, cull, and log defects), have been worked into the relatively simple specifications given in Table 1. It should be noted that the specifications are based on visible factors which can be identified and measured. No judgment as to what the log will produce is required; it is assumed, however, that the logs will be sawed "for grade." In general, No. 1 logs will yield from 64 to 80 percent of high grades (1C & B), No. 2 logs, 40 to 64 percent, and No. 3 logs, 13 to 36 percent, the variation being due chiefly to species differences. On a comparative basis, the lumber from No. 2 logs of the major

species is worth about 75 percent, and that from No. 3 logs about 50 percent of that from No. 1 logs.

The suggested specifications for the structural class of logs (Table 2) are based on a set of principles different from those for factory logs. Position of log in tree is not important. Size of log, both length and diameter, must obviously be considered for the items produced must be cut to definite width, depth, and length. So far as defects are concerned, their size, character, and position are more important than pattern; i.e., than relation to each other or to faces. If defects are so large as to weaken the potential product, they are degraders; if defects do not have this effect then they do not alter log grade. The chief result of log defects here is to disqualify a log. This is different from the factory class where major effect is to raise or lower grade.

Another very important factor is cull. Whereas in factory logs a considerable amount of rot can be present, in structural logs only that which is of surface nature is permitted. On the other hand, stain and scattered insect holes, important degrades in factory logs, are not important here. Straightness is also extremely important. Actually, a great deal more study needs to be given this class of log. For the present however, the specifications shown in Table 2 will be a good guide for graders.

The local or miscellaneous use class comprises all logs above the "poorest log" already defined, and below the factory and structural class. No grades are available or are suggested at this time. Although the value of products from these logs generally averages low as compared with structural or factory products, they should not be under-rated for they may be profitable. The main consideration here is that the products will not stand long shipment but have to be sold locally to be used economically. These logs are not suitable for other types of use.

Grades Applicable to Standing Timber

Although the specifications already discussed are for cut logs, they can be applied to standing timber with a good degree of uniformity. When used in this manner, the two following points must be considered:

(1) Since only surface characteristics can be used, what loss of accuracy will arise from failure to see interior defects? The answer is that undoubtedly there will be some, especially in old-growth timber. It will be at a minimum in second growth. However, studies of local operations should give a correction factor. It is not possible to evaluate the possibilities quantitatively at this time, but best opinion is that accuracy can be held within satisfactory limits.

(2) Since in cruising timber with standard volume tables, 16-foot sections must be used (except for top logs), what will differences in length due to local bucking practice do to accuracy? The general tendency with trained buckers would be to raise final above estimated grades. But an allowance for this can be made. A suggested one permits raising the grade of the basic 16-foot log to that of its best 12-foot section.

Learning Log Grading

In general, experienced timber grades should be able to come within 5 to 10 percent of the final log grade values, or at least as close as volume estimates are generally held. To learn the system the suggested specifications should be studied *on logs*. An office study may be discouraging for it cannot give any indication of the frequency of factor application, and the "self-grading" aspects of the system. Frequently, as many as 75 percent of logs will "class and grade themselves." That is, judgment of one or two very obvious features will "place" the log. Only on a relatively few will a succession of judgments be required. What appears to be extremely complicated, with field experience becomes much simpler.

A very important phase of grading, and one which can and should be studied independently, is the identification and evaluation of log defects. These are abnormalties on the log surface which indicate degrading blemishes in the contained wood. They should not be confused with "cull" material made unusable by rot, dote, shake, insect attack, and which is removed from the product in manufacture, and for which deduction is made in log scaling.

A specification for a clear cutting on a factory log face is given as the distance lengthwise between log defects. In structural logs the size, depth, or location of a log defect may be a

controlling factor in classification. Hence, a good knowledge of such features is essential. Any noticeable variation from clearness—bulge, bump, knot, bark pattern change—is a possible log defect. Particularly important are the inconspicuous features, often over-grown, which indicate deeply buried blemishes. To date, published information on this subject is inadequate. Some will be found in the Forest Products Laboratory publication D1737. A comprehensive bulletin on log defects[1] is now being printed by the Government Printing Office and should be available in early summer. This publication defines most common and some uncommon log defects. It contains photographs and discussions of occurrence and significance. It points out that significance may vary according to potential product, with character of the defect itself, and with relation to other grading factors, particularly diameter. It further emphasizes the principle that in factory logs, effect of a defect is gauged, in general, by its relation to an outer rim of wood with a thickness of about one-sixth of the scaling diameter of the log. In structural logs, on the other hand, deterioration of the center of the log is a critical factor. Although much information can be gained by watching logs sawed up, perhaps the best place to study log defects is on a slab pile where individual defects can be examined at close range, their characteristics studied, and relation to log blemishes gauged. In hardwood factory logs, it is especially important to learn to identify and give proper weight to obscure or inconspicuous features such as over-grown knots, grub emergence holes, and ant damage.

Checking Grades Against Values

Having learned to class and grade logs, what next? The next step is to determine values by grades. For factory logs, values may be approximated from the Forest Products Laboratory publication D1737, which gives average yields by species for each grade, and for individual diameter classes within the grades. But these are for a given sawing thickness pattern. Individual or regional practices may vary from this pattern. Also there may be hidden defects, such as shake or insect damage, which give no surface and only slight end indication of their presence, and which over wide areas may lower product values significantly. Further, there are no standard output figures for use classes other than factory. This means local tests of the various types of logs must be made to establish local values. Timber owners and mill men alike should be interested in such tests which are relatively simple. They can be made by running a group of at least 25 logs of a given grade and species through a mill and keeping a tally of the products. Other important information will be relative overrun data and milling time per grade or class.

Another type of test would be to take a large number—100 say—of logs of a given grade or class and saw part for one type of product and part for another. For example, a test would be to see, when there is a market, how many No. 3 factory logs might better be sawed into ties, and what effect this would have on the product value of the remainder of the class unsuited for ties.

Another test would be to relate specific products to standard grades. How many No. 1 factory logs will be good veneer logs? Can a special veneer grade be set up? If so, what will be the effect of robbing the affected standard grade?

Where Log Grades Will Pay Off

There are many places in the management of timber stands and the conversion of logs into sawn products where the grading system outlined will be of great usefulness. In cruising timber, it offers a technique for localizing the universal tables[2] which are the bases of the modern cruising methods. These tables are based on a "mathematical" tree. The amount of the tree stem included is limited only by very rough limbs or by abnormal taper, and not by current utilization practice in a given region or industry. Softwoods under normal conditions generally are utilized well up to and frequently over the limit used in making the tables; merchantability appears to be limited by size and cull only. In hardwoods, however, limits of merchantability are established by factors other than size and soundness. Even for lumber, fre-

[1] "Log Defects in Southern Hardwoods", by Lockard, Putnam and Carpenter.

[2] "Tables for Estimating Board-Foot Volume of Timber", by Mesavage and Girard.

quently less of a tree is used than is included in a volume table. Therefore, either a correction factor must be developed or a "non-merchantable" log specification be used to bring these tables down to local conditions. A grading system makes this possible. Estimating volume in terms of standard grades will also permit adjustments of data to meet the needs of specific industries. Without any changes in technique, it is possible for a cruiser to report on the volume available if the stand is being considered by a veneer plant, by a standard lumber mill, or by a pallet factory. It is further possible to condition the cruise figures by area and by types of tree. In these days, when integrated use of our forest resources is the keynote, cruisers will find the use of such a system of great help in developing information on the possibilities of operations designed to use the full volume of timber on an average acre.

To forest managers, the usefulness of such a system can be almost unlimited. To begin with, these men engaged in the intricate job of raising and harvesting timber, cannot be expected to be familiar with all the technical requirements of the many possible uses to which their timber might be put. However, the availability of standard specifications governing the relative quality of various pieces of wood which could be cut from the stem of a tree would permit them to proceed with assurance toward developing as many high quality pieces as possible. Not only could they appraise the existing "ripe" timber, but they also could hold for the future the trees which are now low grade, but which have the basis for future quality, and could select for cutting those trees the quality potential of which has been reached, be it high or low. Using grade specifications, they could also soundly define inferior timber which has no present value and no future prospect and which should be girdled or poisoned to make room for a new crop. Finally, by the process of careful selection they could, over the years, weed out the trees which are genetically inferior and leave those genetically superior.

In getting the most out of trees (particularly in integrated operations) an important factor is the supervision given timber harvesting operations, especially the log making phase. It is very easy to demonstrate that poor log making can readily result in significant loss of potential values. A standard set of grades could be a very useful tool for woods supervisors in training woods labor, especially apprentices, to prevent such losses. Operators of certain types of mills would find in log grades a precise basis for accepting or rejecting logs. If such acceptance or rejection were not possible or desirable, it would permit sound judgment to be made as to the necessity for installing special equipment for logs to which the existing equipment might not be adapted. For example, there are certain classes of logs for the milling of which portable mills at or near the woods might be the best answer. Such logs might contain so much defective or waste material, or be so crooked that to transport their entire volume would be uneconomical. Other better classes of logs might best be hauled whole into a central plant where the inherent values could be recovered with more precise or more efficient machinery. Another determination might be differences in sawing methods for logs of different characters. Some might be best handled by sawing round and round, others by sawing through and through. The knowledge of the availability of large quantities of logs of a given character might also justify the operator in developing new markets and a better integrated operation.

Finally, the whole process of marketing logs would be improved. The seller or his agent could appraise his timber himself more accurately and be in a better bargaining position. The position of the buyer would be improved because he could more accurately determine the value by grades than guess at an average value to represent the usual wide range of values involved in woods-run logs.

TECHNICAL SESSION II

Monday, June 26, 1950, 1:30 P. M.

General Subject: Shipping Containers, Developments, Problems

Chairman: C. F. Van Epps, Engineer in Charge of Materials Engineering Department, Stromberg-Carlson Company, Rochester, New York (Board Member, Northeast Region, FPRS)

Recorder: D. W. Walters, Managing Engineer, Inland Empire Industrial Research, Spokane, Washington (Secretary-Treasurer, Inland Empire Section, FPRS)

D. W. Walters, C. F. Van Epps,
J. F. Hamilton, presiding.

Recent Developments in Wirebound Containers for Fresh Fruits and Vegetables

C. H. Jandt

Package Research Laboratory, Pasadena, California

It is the purpose of this paper to briefly outline the economic conditions that have been the impelling motive in bringing consideration and development of new containers in the fresh fruit and vegetable industry. Illustrating the trend are descriptions of two vegetable containers which have come into usage during the past year. As a matter of current interest a wirebound crate closing machine is commented upon. Also discussed is the flash cooling process for pre-cooling lettuce.

THOUGH a basic similarity of products and problems exists in the several fresh fruit and vegetable producing areas of the United States, each has its specific troubles and for the purpose of this discussion only the Western area will be considered.

Tradition and the Fruit and Vegetable Package

The fresh fruit and vegetable industry has not been one to quickly and easily adopt changes in its customs or containers. In fact many of the shipping containers now in use have gained such sanctity, simply because of long years of usage, that, until quite recently, any suggestion of change, either as to type or dimension was regarded as rank heresy.

Had these containers been developed through scientific research and to meet an unchanging condition, this attitude would perhaps be understandable but such was not the case. In the majority of instances crates were designed by rule of thumb and for conditions which passed out of existence years ago.

As a typical example the orange crate may be cited. We are told that when the California citrus industry was in its infancy, oranges were packed in egg cases, probably because egg cases happened to be available. As the industry grew, an orange crate of practically the same design and dimension as the egg case was adopted as the standard orange crate—and fifty years later it is still the standard. The same crate, the same pack that was made and used when oranges were retailing from the original shipping container, canted against the wall of the grocery store, for *eating* purposes, is still used today when 95 percent of the oranges are sold from a bulk bin and better than 85 percent are consumed in the form of juice! Is it not within reason to assume that with such a radical evolution in retail merchandising that crate styles and packing practices could be developed which would reduce handling costs and better fit modern retailing methods?

However, the sacrosanct position of some of the principal containers in the fruit and vegetable industry is at long last being questioned. Economic conditions now prevailing compel a review and analysis of all of the phases of operation in this gigantic business in an effort to reduce costs to a point permitting profitable operations. For perhaps the first time in its history the fruit and vegetable operators are combining in the establishment of a scientific research program to undertake studies of the several phases of the processing and packing of fresh fruits and vegetables. Containers will be checked to determine whether changes in size, style, or type will result in more efficient and economical handling.

The Economics of Package Development

One of the serious economic problems confronting the perishable shipping industry is that of transportation costs. Freight rates have soared during the past few years and the western shipper, always at a disadvantage because of his remoteness from the large consuming centers of the United States, is threatened with being priced out of the market by the more favorably located competitive growing areas.

Since there are no package rates on fruits and vegetables, these commodities move on either published or actual weight and the transportation charge is assessed on the weight

of the commodity plus the *weight of the container*. Therefore it is not only desirable but vitally necessary to hold the tare weight of the shipping container to an absolute minimum.

Illustrating this need is a recent published statement of T. R. Phillips, Traffic Manager of the Western Growers Association, in discussing certain proposals by the rail carriers to increase the published weights of lettuce and carrots. Mr. Phillips stated that an increase of one pound per crate in the lettuce and carrot tariffs would impose an additional transportation burden upon western growers of $420,000 annually.

Wirebound Containers

This fact has centered interest on the wirebound shipping container which, by virtue of its design, has less tare weight than other types of wooden containers; the differential varying from 2 to 4 pounds when compared with comparable sizes of nailed crates.

But when it is realized that the rail carriers during 1948 paid in excess of 12½ millions of dollars in loss and damage claims on fruits and vegetables it becomes apparent that any reductions in container tare weights, regardless of the type, must be accomplished without impairment of the ability of the container to deliver its contents in good condition at destination. Loss and damage claims are a part of the operating cost of the carriers and as such contribute a reason for higher freight rates.

The wirebound crate has achieved its light tare weight by means of a design employing thin veneer boards on the several surfaces of the crate and transferring the stress and strain from the wood members to steel girth wires encircling the crate.

The strength of this type of crate construction has been proven by exhaustive laboratory tests and it is further attested by the findings of such agencies as the Railway Perishable Inspection Association in actual shipping experience.

This agency, in co-operation with the United States Department of Agriculture, made a check of the arrival condition of celery in wire bound and nailed crates during December, 1948 and January and February, 1949. The results of this survey have just been released and reveal the following comparative information:

	Wirebound Crates	Nailed Crates
Number of carloads unloaded	2,015	1,655
Number of crates requiring recoopering	13,478	74,858
Average number of crates per car requiring recoopering	6.7	45.2
Number of crates delivered "bad order"	2,618	10,512
Average number of crates per car "bad order"	1.2	6.4

These figures are significant not only as proof of the carrying ability of the wirebound crate, but since a broken crate results in a damaged commodity, demonstrates the economic advantage of delivering a greater percentage of saleable merchandise.

The Need to Develop Packaging Designed for Today's Merchandising

There is a second factor which is impelling interest in new types and designs of containers. Merchandising of perishable commodities, both on the wholesale and retail levels, has undergone material changes in recent years. The large chain groups have been particularly active in their research work and analysis. These groups are vitally interested in the development of packing practices and shipping containers that will deliver a greater percentage of *saleable* merchandise in the crate at destination. Many of the prevalent packing practices, particularly in vegetables, inflict a great amount of mechanical damage to the commodities in the crate and result in unsaleable merchandise which must be heavily trimmed or thrown away.

In other instances a change in the method of handling commodities at receiving markets makes advisable related changes in packing practice.

In an effort to aid in the solution of some of these problems the Package Research Laboratory has designed several wirebound crates which have, in shipping practice, established their economic worth.

The standard method of packing tomatoes has, for many years, been a place pack in the nailed lug. In this method tomatoes are handled individually by skilled packers who wrap each tomato in a tissue wrap, then place the tomato in the lug according to a diagram pack.

Costs of this operation vary from 12¢ to 14¢ per lug for labor and approximately 7¢ per lug for the tissue wraps.

During past years tomatoes were sold in the receiving market largely in the original lug container. This practice has changed. Today, the best information we have, reveals the fact that 85 percent of the tomatoes shipped to eastern markets are repacked into small cellophane tubes holding three or four tomatoes. In this repacking operation the tomatoes are dumped from the shipping container onto a belt, the tissue wraps removed and the tomatoes sorted according to the various stages of ripeness. Therefore there is no justification for the expense involved in the use of wraps and the labor necessary to place pack the fruit.

A New Tomato Crate

To supply the demand for a more efficient and economical manner of handling tomatoes from point of origin to the repacking plants, the Package Research Laboratory designed a crate involving a radical departure from the old, time established lug box.

A wirebound crate designated as the Tab tomato crate (see Fig. 1), with inside dimensions of 18¾ inches length, 11$\frac{5}{16}$ inches width, 11$\frac{5}{16}$ inches depth was designed to carry approximately 60 pounds of tomatoes. After the tomatoes have been sized and graded in the packing house at the shipping point, they are simply poured into this container at a labor cost of 2¢ to 3¢ depending on the packing house set-up and the prevailing labor rate. The saving accomplished is a very worthwhile economy.

Fig. 1.—The "Tab" tomato crate.

All question of the ability of the wirebound crate to carry the tomatoes without damage was dissipated by the arrival of both rail and truck shipments, some on 15-day hauls, with practically no serious bruising. In fact, receivers reported less bruising than in the wrapped place pack in the nailed lug.

The use of these crates has accomplished a reduction in processing costs, provided a container of minimum tare weight and supplied the buyer good merchandise with a minimum of loss and damage.

A New Lettuce Crate

Another recent development in wirebound containers of which we feel justifiably proud, is the wirebound "Square" lettuce crate (see Fig. 2). Designed after considerable investigation at both the shipping and receiving ends of lettuce operations, this crate delivers more *saleable* lettuce to the receiver because it eliminates

Fig. 2.—The "Square" lettuce crate.

much of the mechanical damage at the time of packing and affords a maximum of protection to the lettuce during transit.

For the benefit of those not familiar with lettuce or lettuce packing, it may be explained that the existing standard lettuce crate is oblong in shape, the dimensions being 21⅝ inches long, 17½ inches wide, 13 inches deep. This crate came into being many years ago and at a time when an entirely different lettuce than we have today was being grown. The heads then consisted of a rather small hard center, the remainder being an abundance of soft cover leaves which, with the light pack customary in those days, fitted nicely into the standard crate without any appreciable damage to the lettuce. However, years of seed breeding have developed strains of lettuce in which the heads have the hardness of a bowling ball, sizes are larger and present day lettuce has few cover leaves when packed.

A size of lettuce preferred by receivers generally is the so-called "four dozen" or 48 heads to the crate, which are packed in three layers of sixteen heads each. These layers follow a square pack pattern in which four heads of let-

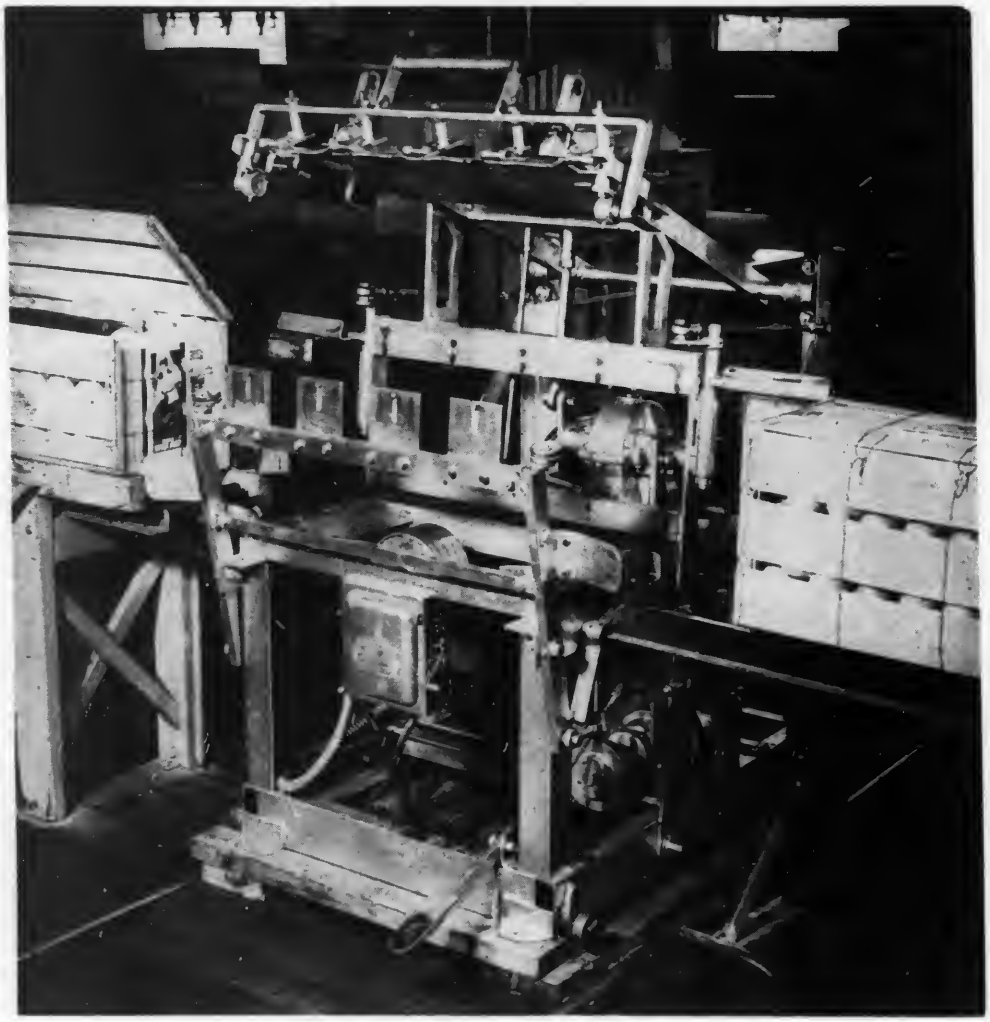

Fig. 3.—Semi-automatic crate-closure machine.

tuce are placed lengthwise of the crate and four heads crosswise. Obviously, with this pack the present standard crate is either too long or too narrow—as a matter of fact it is both! The actual result is that the lettuce is forced into the crate by a heavy pressure sufficient to cause considerable mechanical injury to the lettuce as well as breakage of the crate in transit. This of course means that the receiver will have to trim off all damaged lettuce leaves before the head is saleable and therein come the complaints.

The wirebound "Square" crate has a length of 19¾ inches, width of 19¼ inches and a depth of 13¾ inches. By reconciling the dimensions of the crate with the physical displacement of the lettuce we have succeeded in developing a crate which virtually eliminates any mechanical damage during the packing operation. Substantial commercial shipments have been made from California to the Eastern Seaboard with practically no breakage occurring in transit. .

Reducing Closure Costs

During the early years of the development of wirebound shipping containers, labor rates were low and shippers were not inclined to make extensive cash outlays for labor saving machinery. Therefore, in the main, all crates, wirebound or nailed, were closed by a manual process.

Today, because of high labor rates, shorter work hours and less control of help, the emphasis in packing houses is directed toward speed and mechanization in all operations. This condition generated a demand for a mechanical device that would close wirebound crates properly and quickly.

J. H. Platt & Sons, of Los Angeles, Californina, inventors and manufacturers of packing house machinery for many years, recently undertook the job of developing a closing machine for wirebound crates. Their inventive genius has produced a series of machines designed to meet the diversified needs of the perishable shipping industry.

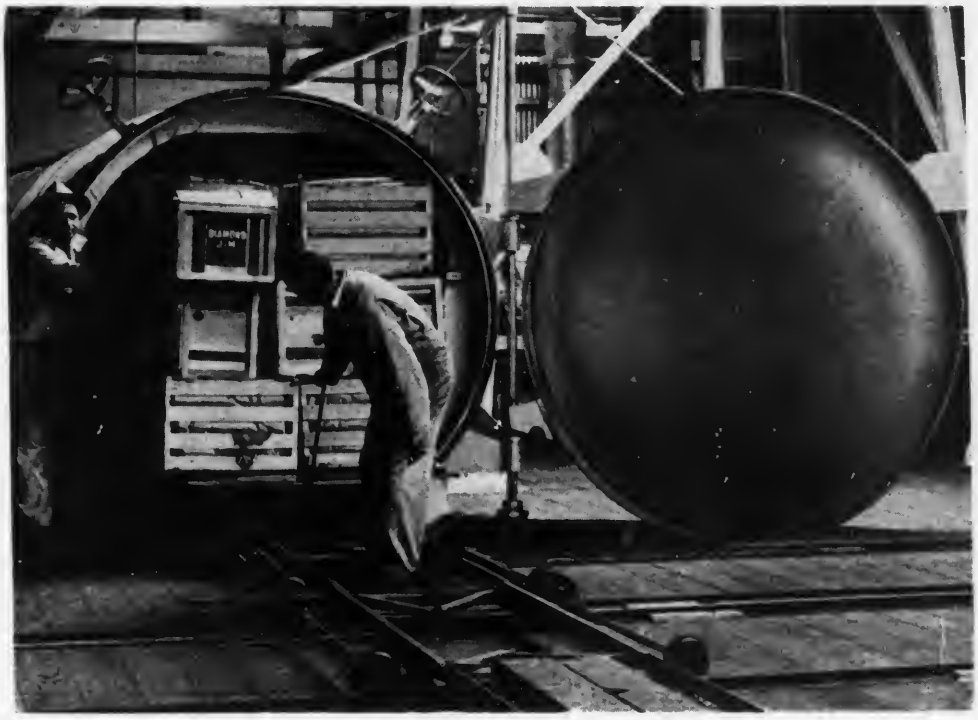

Fig. 4.—Flash cooling lettuce.

They manufacture a manually operated machine for use by small shippers which has a capacity of about 250 crates per hour. A second machine (see Fig. 3) is a semi-automatic closer, driven by electric power, which has a capacity of 300 to 400 per hour.

Both of the aforementioned machines have an interrupted cycle wherein the press operator manually aligns the side and top loops for engagement and closure. A third machine, which the Platt company has designed, is a fully automatic machine which requires no manual assistance at any point in the closing operation. This machine has a capacity of 500 to 600 crates per hour.

Reducing Shipping Costs by Flash Cooling

Within the past year a process of "flash cooling" lettuce has been introduced in the California shipping districts, which, based on results attained in commercial shipments, promises to accomplish a material economy in shipping costs and to reduce deterioration of lettuce during the transit period. This method also obviates the necessity for the practice, in the shipment of lettuce, of blowing from 10 to 17 tons of snow ice over the load in the refrigerator car for the purpose of rapidly reducing the pulp temperature of the lettuce. It also eliminates the tons of top ice, reduces crate breakage and materially facilitates unloading at destination.

In the flash cooling process (see Fig. 4), the lettuce packed in crates is placed in a chamber capable of withstanding a high vacuum. The air is withdrawn from the chamber and as this takes place the vapor pressure is lowered. In actual practice steam jets are used to entrain the air vapor mixture that is formed within the chamber due to the surface moisture, present on all vegetables, being flashed into steam.

Evaporation cooling does not produce dehydration. It merely removes a small percentage of the available surface moisture which is in immediate contact with all surfaces of the head of lettuce. Under the vacuum cooling, the head is merely cooled and the small amount of moisture remaining on the lettuce leaf is not adequate to cause slime or decay within the normal expectancy of time required for distribution.

The time required to reduce the pulp temperature of the lettuce to 32° F. is approximately 30 minutes.

Receivers of lettuce in the terminal markets have indicated their approval of the flash cooling process because of the satisfactory condition of the lettuce at destination.

With the present progressive attitude on the part of perishable shippers toward scientifically designed crates as evidenced by their support of research programs currently underway, another year may produce concrete conclusions as to what constitutes the most effective, efficient, and economical shipping container.

Discussion

Mr. Armin Elmendorf (Elmendorf Research Inc.): Would you please briefly outline the tests you use for evaluating wirebound boxes? Do you prefer to test the box loaded or empty? Do you use a shock test or a static loading test, and if the latter, a diagonal compression or corner-to-corner compression test?

Mr. Jandt: Wirebound boxes and crates are subjected to tests which simulate conditions expected in actual shipment. These tests are discussed in the paper presented by Mr. J. M. Ladd.

For rough handling, the boxes are always tested with either actual contents or until a definite cycle of falls or impacts is completed. For fruit or vegetable containers, our rule is that boxes must withstand 30 to 40 falls in the 14 foot revolving drum which is 2 to 3 times the rough handling expected in domestic shipments. This practice has been responsible for the small amount of damage reported for fruit and vegetable shipments in wirebound boxes.

To evaluate the box for stacking, tests are made in the compression machine with load applied flat over the entire top of an empty box. Essentially, this is a static loading test as load is applied slowly. We expect these fruit or vegetable boxes to withstand 4 or 5 times the expected stacking loads to provide a proper margin against shocks or impacts.

Method of Utilizing and Fabricating Waste Lumber

Albert E. Cranston, Jr.
President and General Manager, Cranston Machinery Co., Inc.

Short cuts and waste pieces of lumber have been utilized in the manufacture of wooden containers for many years. The steel corrugated fastener method has been highly mechanized and widely used for the salvage of pine and some species of fir, particularly in the food container box. The splined-end method of glued-type ends is becoming more popular due to the increased use of white fir and larch lumber in the wooden box industry. This system is one that can be used on all lumber species and produces a product that is strong enough to meet the most stringent tests. By the use of automatic equipment and a good glued joint, short pieces of waste can be built up in length and used along with the regular cuts of shook for box ends.

Historical Background

FOR the past 30 years certain types of waste lumber have been salvaged by various means in box factories and lumber mills. One method particularly used in the wooden box container field has involved the use of steel corrugated fasteners. At first fasteners were furnished in the cut lengths and driven by hand with the use of a hammer and a solid bench. Later, foot pedal machines were developed, and still later automatic hopper feed machines came into prominent use. Today machines are available that will hopper-feed, staple, equalize, and rip the finished box end to size in one operation and at the very high speed of 50 or 60 double-thickness ends a minute. The fasteners for these high-speed machines come in 50-pound coils and are cut for length and driven into the shook by the machine.

Various types of glue operations have also been used in more recent years. Some of the more popular methods include the Strong end, as developed and engineered by Curt Strong of The Weyerhaeuser Timber Company, Klamath Falls, Oregon. A similar principle is used in the Goff machine, which was developed some time later. Another very popular method is the splined end, which was first introduced by Dan Shook and has been used in the orange box district for the past 20 or 25 years. Some plants have used the Linderman-type ends successfully on certain types of containers. Several other less popular methods have also been developed.

Steel Corrugated Fastener Method

With the use of the foot pedal-operated hand machines, most of the end stock was built up of two pieces of otherwise waste lumber. The fasteners were also used to reinforce a check or crack in a one-piece box end that otherwise would have had to be rejected.

As labor costs increased and it became necessary to save more of the waste material and to utilize smaller pieces, there developed a need for a faster and cheaper method of waste salvage.

The Cranston Machinery Co., Inc. eventually developed such a machine, and in about 1932 the first were put on the market in the states of Washington and Oregon. The early models hopper-fed two-piece end stock of predetermined widths at a very rapid rate. Later the machines were redesigned to handle stock of random width, and equalizing and ripping attachments were added. One of these machines is shown in Fig. 1.

This machine is operated by two men and can produce upwards of 50 double ends per minute. The complete process of stapling, equalizing, and ripping is done in the same operation. No additional labor is required. This particular operation is at the Lassen Lumber and Box Co., Susanville, Calif., where the machine shown is fabricating orange box centers by stapling the 4/4 inch thickness with two staples on one side and one on the other side. The ripsaw attachment is directly behind the fastener driver, and the saw to the right is part of the equalizer attachment.

Multiple-Piece Container Ends

The latest development in hopper-fed corrugated fastener-driving machines embodies pneumatically-powered, electrically-controlled equipment that will fasten two or more random-width pieces together automatically and equalize them to length in the same operation, as

Fig. 1.—Cranston shook splicer producing orange box centers.

Fig. 2.—Hopper-fed machine for driving corrugated fasteners, pneumatically powered and electrically controlled, fastens random-width pieces and equalizes them to length.

shown in Fig. 2. This machine is operated by one man and will produce over 25 double ends per minute. A wide variety of fastener combinations is readily obtained.[1]

Glued-Spline Method of Salvage

Another method of saving waste lumber involves insertion of a glued spline into the end grain of the wood. This method is most popular in the salvage of associated species of pine lumber such as white fir and larch. Due to the splitting and checking characteristics of these species during the drying and processing stages, they are not adaptable to fastening by the steel corrugated fastener method.

This type container end is usually manufactured by inserting a $\frac{5}{16}$ by $\frac{5}{8}$-inch spline into the end grain of the box end, as shown in Fig. 3. The spline size is usually maintained

Fig. 3.—Container end with spline inserted into end grain.

regardless of the thickness of the box ends. Tolerance between the spline dimensions and the groove is held to a minimum, due to the fact that the press action of the joint is a big factor in setting the glue up properly. However, after the box is assembled, the nails driven through the sides of the box and into the spline are long enough to protrude through the spline and into the body wood of the end stock, and thus lock the spline in place. This gives the finished end sufficient strength for most container purposes without complete reliance on the glued joint. This feature is more prominent in the spline-type end than in other glue processes. The spline also serves as a stiffener to prevent warpage and distortion during storage time. The splined end can be made up of one or more pieces of stock to reach a desired box end width.

Automatic Splining Machine

Several splining machines have been built for fabricating fruit container ends. In the past these machines have been engineered and built by various box plants at a very high manufacturing cost.

Realizing the necessity of an automatic splining machine, particularly where white fir and larch are being used, the Cranston Co. has undertaken development of a standard-model, hopper-feed machine for this purpose, as shown in Fig. 4. A new model machine will be in operation at the Setzer Forest Products plant at Sacramento by midsummer of this year.

This machine will be capable of producing container ends 8½ by 10½ inches up to 14½ by 16½ inches in size. It will have a top speed of over 50 double ends per minute, making 100 ends after they are resawn. The machine will also trim for length and rip for width at the same operation.

Short Cuts Salvaged

Carrying the waste salvage a step further, the company has developed an automatic machine as shown in Fig. 5 for butt gluing end stock of two or three short pieces into one piece of the proper length for various sizes of container ends (Fig. 6). The small blocks are taken from the wood conveyor and placed in the hopper of the machine. Here they are trimmed for length and, if necessary, cut for width. Then they are tongued and grooved, glue is spread on the joint, and they are squeezed together. The finished block is held under pressure for a short time to let the glue set up. All of these operations are done on the machine automatically.

The built-up section is then processed along with the regular-length waste stock. It is run through a corrugated-fastener-driving machine and becomes either the center part of a three-piece box end or one part of a two-piece end. It can also be processed by the spline method, along with the regular stock.

Taking 12 inches as an average length of container end, this process will effect a salvage

[1] Anon. Machine Automatically Fastens Multiple-Piece Container Ends. 1948. The Wooden Box and Crate, Vol. X, No. 3.

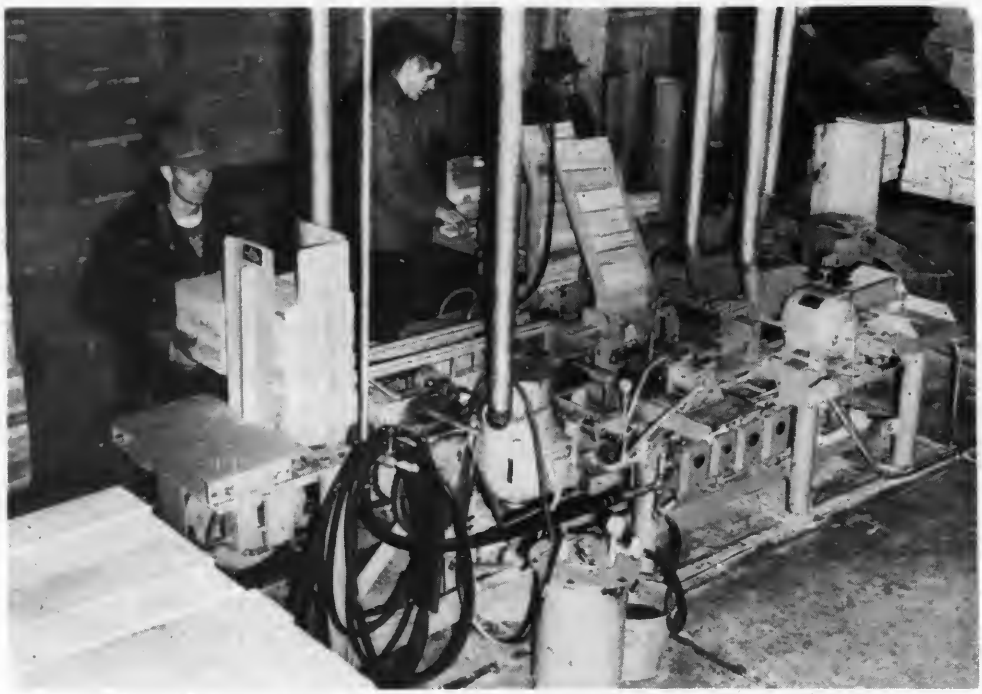

Fig. 4.—Automatic splining machine under development by Cranston Co. for fabrication of fruit container ends.

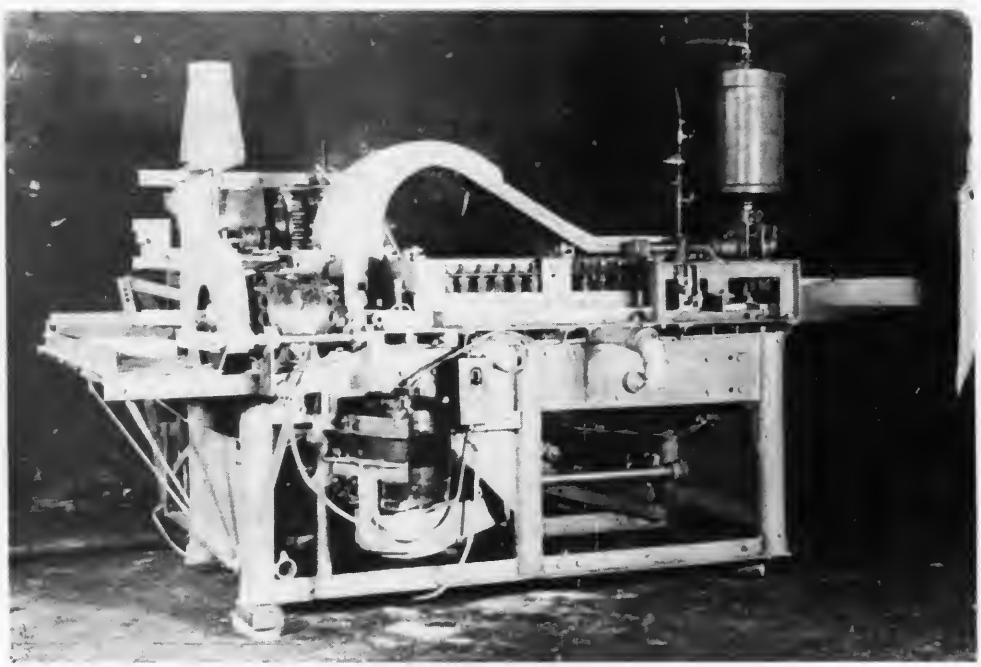

Fig. 5.—Automatic machine developed for butt gluing end stock for container ends.

Fig. 6.—Butt joint devised for butt gluing container ends.

means for any material 4 inches or longer in length and 3 or 4 inches in width. These blocks can be handled very fast and economically with a minimum of labor cost.

Summary

The problems of salvage on waste enter into two different groups. One group has to do with salvaging what might be called popular or premium species of lumber. This problem deals with saving every scrap of wood that can be put to some practical purpose economically. The trade has recognized the steel corrugated-fastener method to a large degree in this group, particularly in wooden containers.

The second part of the salvage problem seems to be that of reenforcing and improving on lesser used species of box lumber, such as fir and larch. This part requires that the method of salvage produce a finished article that will compare with the product manufactured from the so-called standard species and grades of lumber. The spline method produces a comparable product from less adaptable species of lumber and can be used in salvaging both types of material.

Discussion

Mr. J. M. Ladd (General Box Co.): How thin may container material be, and yet be fabricated by the splined method, that is, by inserting a spline into the end grain of the material?

Mr. Cranston: As far as I know, the thinnest container material that has been reclaimed by this method is orange box ends which are as thin as $\frac{9}{16}$ of an inch. However, I see no reason why container material of $\frac{3}{8}$ inch or $\frac{1}{2}$ inch thickness could not be salvaged by this method. The speed of assembling these pieces, along with their dollar value after completion, in comparison to the cost of a similar solid piece of material would determine the practicability of the process.

Mr. C. F. Van Epps (Stromberg–Carlson Co.): Are we overdesigning our boxes as we generally do in furniture?

Mr. Cranston: There are perhaps some types of boxes that have been submitted to the trade that were overdesigned. However, these boxes seldom reach the trade due to manufacturing cost or other undesirable features. The railroad restrictions on containers, and the desirability of saving scrap lumber, along with the constant effort to lower the footage in a container, are responsible for most of the changes in containers.

Mr. Ransame (Oregon State College): Are there any experiments with butt-jointed short-blocks using finger joints?

Mr. Cranston: There, no doubt, have been experiments along these lines, but, as far as I know, nothing practical has been developed for butt-gluing short blocks on the end grain of the wood. Short blocks have been glued on the end grain by the use of a tongue and groove, usually of the tapered design, to eliminate as much as possible the moisture factor in regard to the glue.

Mr. Don Burnet (Burnet Box Co.): Who is responsible for the acceptance and inauguration of technical research developments? What course is open when the industry itself is so tradition-bound that most all change is opposed?

Mr. Cranston: Design changes in containers are due to railroad restrictions, efforts to decrease the footage or cheapen the container from the manufacturer's standpoint, or sometimes the users themselves request a change due to advantage in handling or merchandising.

Apple and pear growers are accepting the splined end which has just recently been offered them. Some growers are, of course, skeptical of changing from the conventional container, but in the past it has been only a matter of time until this opposition is overcome. This, of course, holds true only if the change is as good as, if not better than, the conventional container. I feel confident that the splined end will be accepted one hundred per cent in the near future by the apple and pear growers.

Mr. J. B. Grantham (Oregon State College): In making glued-up products from shorts, have you experimented with gluing plain butt joints, that is, without tongue and groove, scarf, or finger joint?

Mr. Cranston: There has been considerable experimenting with glued joints to salvage short stock. These pieces can be saved with a plain butt joint if the joint is made on the side grain, but they have never been successfully glued on the end grain, to my knowledge, without the aid of a tongue and groove joint.

What is the comparative cost of salvage between the fastener method and the glued-end method?

Mr. Cranston: The cost of either of these two methods will vary considerably in different plants. Where the fastener method is applicable it is the cheaper method due to two main reasons. First, there is no footage loss in the material, and the cost of manufacturing the spline is eliminated.

Tests of Strapped and Lightweight Lettuce Crates

Earl C. Myers
Director of Research, The Wooden Box Institute

Laboratory, packing, and transportation tests of lettuce crates were made to determine the effectiveness of girthwise straps in increasing strength of both standard crates and crates made with thinner slats, head rails, and posts. Results showed that strapped crates performed better than similar unstrapped crates and that strapped lightweight crates were nearly as strong as standard crates not strapped.

Introduction

OVER 30 million lettuce and carrot crates were used in the West and Southwest last year. The dimensions and construction of both of these crates are similar. The crate consists of two heads, side and bottom slats and a cover. The heads are of framed panel construction. The head frame (two rails and two posts) is joined with a spike at each corner through the rail into the post. One panel and two slats are nailed to the head frame to form the complete head. Side and bottom slats are nailed to the heads to form the crate. After packing, the cover is nailed to the crate heads. All parts except the cover are usually sawn wood. The cover is veneer, consisting of slats and cleats joined by metal staples or stitches.

Most vegetables, including lettuce and carrots, are normally bulge-packed with ice in the container, and refrigerator cars are loaded with ice on and between the crates. Crates are loaded on-side lengthwise. This method of loading causes severe stresses and deflections in the slats when the car is subjected to switching impacts. Recently, railroads have taken steps to restrict the cover bulge and crate girth in an effort to reduce the damaging effect of this rough handling. The presence of melting ice in and near the package results in some increase in the moisture content of the wood.

Vegetables are perishable and must be handled through the packing shed and into refrigerator cars or trucks with great speed. Because of this and other reasons the fresh vegetable industry has become highly mechanized. Packing sheds have been built and equipped to do specific jobs with particular materials, including packages. Conveyors, packing stands, and crate framing and lidding machines have been installed in most sheds to handle the nailed vegetable crate. In addition, containers now in use are adaptable to common carrier equipment, both rail and truck. When considering changes in container specifications, thought must be given to the effect such changes may have on the use of existing shed and carrier equipment. The advantages of any container specification change must be great enough to more than balance the cost of changes or replacements of equipment that would be required.

To develop strength data on suggested possible changes in the vegetable crate and to evaluate the effect of these changes on existing shed and carrier equipment, the Wooden Box Institute performed laboratory tests on standard and lightweight lettuce crates, both strapped and not strapped, and in addition made packing shed and transportation tests on standard lettuce crates, with and without straps.

Crates Tested in the Laboratory

Sixty crates, all made with white fir rails, posts, head slats and panels, and side and bottom slats, were tested in the laboratory. Unitized covers were made with spruce veneer cleats and slats. All crates were assembled by driving three fourpenny, cement-coated box nails through the end of each slat into the head frame. The framed crate heads were assembled with each rail fastened edgewise to the end of each post with one eightpenny, cement-coated box nail, three threepenny nails through the panel into each rail, and four threepenny nails through each end slat, two into the post and one into each rail. The covers were attached with six fivepenny, cement-coated box nails through each cleat into the rail. The dimensions of all crates were 13¾ inches inside depth, 17½ inches inside width, and 24½ inches outside length. All head slats were $\frac{7}{32}$

by 2⅞ by 12¾ inches. All head panels were $\frac{7}{32}$ by 7¾ by 12¾ inches. Cover cleats were $\frac{5}{16}$ by 1¼ by 16¾ inches. All crates had three cover slats, each 1/9 by 4¾ by 24¾ inches. Other crate specifications were as follows (all dimensions shown are in actual inches, nominal thicknesses of slats are $\frac{1}{32}$ inch greater):

Crate A, standard vegetable crate:

4 rails 1⅛ by 1⅜ by 17½
4 posts 1⅛ by 1⅜ by 11
9 slats $\frac{9}{32}$ by 3¾ by 24½

Crate B:

Same as crate A, with the addition of one ¼ by 0.015-inch flat band girthwise at the center.

Crate C:

4 rails 1⅛ by 1⅜ by 17½
4 posts 1⅛ by 1⅜ by 11
9 slats $\frac{7}{32}$ by 3¾ by 24½
1 flat band ¼ by 0.015 girthwise at center.

Crate D:

4 rails ⅞ by 1⅜ by 17½
4 posts ⅞ by 1⅜ by 11
9 slats $\frac{7}{32}$ by 3¾ by 24½
1 flat band ¼ by 0.015 girthwise at center.

Crate E:

4 rails ⅞ by 1⅜ by 17½
4 posts ⅞ by 1⅜ by 11
9 slats $\frac{9}{32}$ by 3¾ by 24½

Conditioning of Crates

All crates for laboratory tests were assembled from dry shook at 10 to 12 percent moisture content. Some crates were then conditioned before testing to "moist" or "wet" to simulate the range of moisture content values that might prevail in a refrigerator car with melting ice. "Dry" crates were tested at the same moisture content as when nailed (10 to 12 percent). "Moist" crates were sprayed with water for 3 to 5 hours immediately before test. The moisture content of the moist crate slats varied from 31 to 67 percent and averaged 42 percent. "Wet" crates were soaked in water for two days. The moisture content of the wet crate slats ranged from 63 to 82 percent and averaged 72 percent.

Laboratory Test Procedure

After conditioning of the crates, each was filled with a dummy load and lidded. Crates B, C, and D were strapped girthwise at the center. The dummy load weighed 100 pounds and consisted of dummy apples in bags and a wooden filler box at the center of the load. The filler box was designed to give the proper bulge and girth. The actual average measured cover bulge on crates, both strapped and not strapped, was $2\frac{1}{16}$ inches. The actual average measured girth was 66¾ inches for the crates that were not strapped and 63⅛ inches for the strapped crates. Present railroad tariffs permit a 2½-inch bulge and 68¼-inch girth. Crates ready for test are shown in Figs. 1 and 2.

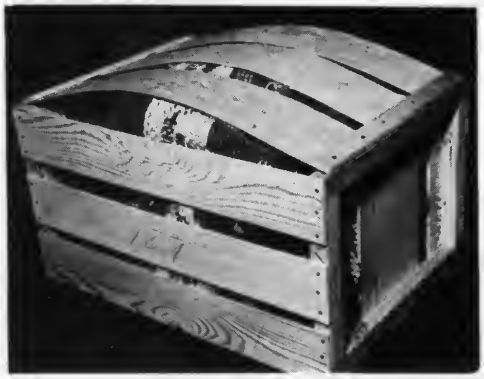

Fig. 1.—Standard lettuce crate (A) packed and lidded ready for the incline-impact test. This crate has $\frac{9}{32}$-inch side and bottom slats and 1⅛-inch rails and posts.

Fig. 2.—Lettuce crate packed, lidded, and strapped ready for the edgewise-drop test. This crate was tested after soaking in water for 48 hours. It has $\frac{7}{32}$-inch side and bottom slats and 1⅛-inch rails and posts (Crate C). Strap is ¼ by 0.015-inch flat steel band.

Two kinds of tests were made, edgewise-drop and incline-impact.

Edgewise-drop tests were made by dropping the filled and lidded crate edgewise from heights of 12 inches. Drops were made in sequence on the edges of each end and then on the bottom-side edges and the top-side edges. Drops were continued until some part of the crate was completely broken or unfastened. Results were recorded as the number of drops to cause failure. A drop test is shown in Fig. 3.

Fig. 3.—Standard lettuce crate (Crate A) suspended for first drop in 12-inch edgewise-drop test. Operator is about to trip release, permitting crate to drop onto concrete slab. Subsequent drops will be made on other edges of crate in standard sequence. This crate had been sprayed with water for four hours prior to test.

Incline-impact tests were made on a standard conbur testing machine. The crate under test was mounted on the dolly lengthwise on-side in front of a "load" box and with its leading end projecting 6 inches beyond the front edge of the dolly. The load box was filled with sand bags. The combined weight of the bags, sand, load box, and dolly was 413 pounds. The dolly was pulled up the incline until the leading end of the crate being tested was a multiple of 6 inches from the barrier. Four runs were made from each distance. The first four runs were made from 6 inches, the second four from 12 inches, then 18 inches, and so on. The runs were continued until the crate failed. Results were recorded as the energy absorbed by the crate. The energy absorbed is the product of the sum of the vertical components of distance through which the crate moved and the total weight (crate, contents, dolly, load box, bags, and sand).

The drop test was designed to measure the resistance to rough handling of individual crates. The incline-impact test was designed to measure the resistance of the crates, when loaded in refrigerator cars, to impacts caused by rough handling of the cars, especially in switching yards.

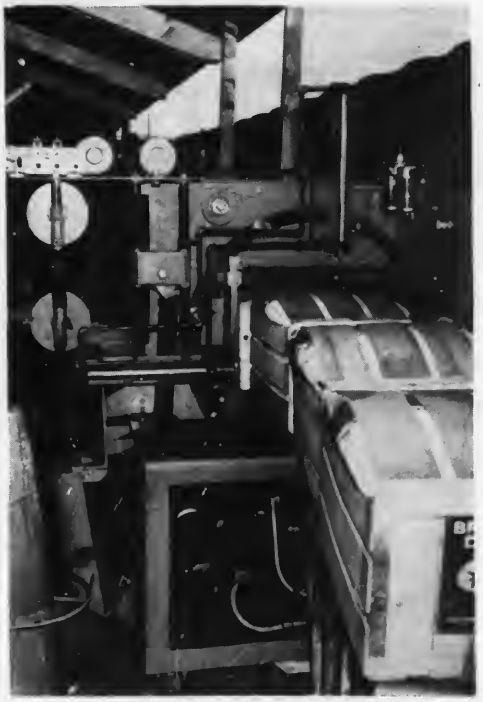

Fig. 4.—Automatic wire-tying machine used in packing-shed tests. Machine has air-powered arms to hold crate sides and cover in compressed position while wire is wrapped around crate and tied.

Fig. 5.—View of partially loaded test car. Loading is in accordance with standard pattern and bracing method required by railroad tariffs. The end gate and two rows of strapped crates along one side of car are shown.

Fig. 6.—Typical failure of lettuce crate in edge-wise-drop test. This is a standard lettuce crate (A), soaked for 48 hours prior to test. Failure occurred after the seventh 12-inch drop, and was caused by nails pulling.

Fig. 7.—Failure of lettuce crate in incline-impact test. This crate was made with $\frac{3}{32}$-inch side and bottom slats and was strapped with one ¼ by 0.015-inch flat steel band (crate C.). Just before the test the crate was sprayed with water for 3½ hours. Failure occurred after the crate absorbed 6,560 foot-pounds of energy.

Packing and Shipping Tests

Packing tests were made at the K. R. Nutting Co., Salinas, Calif. Tests were restricted to standard lettuce crates with and without girthwise straps. An automatic wire-tying machine using 15½-gage galvanized wire was installed and operated by the Mutual Binding Machines Co., Oak Grove, Oreg. The machine is shown in operation in Fig. 4. The packing tests were designed to determine the ability of the wire-tying machine to handle the output of the shed without interfering with normal production, and the extent of shed equipment alterations or additions required.

The regular carloading method was used for the test cars. A partially loaded car is shown in Fig. 5. Inspection of cars at point of origin was made by the research staff of the Western Growers Association. This organization also provided inspection service on three test cars unloaded in New York. Two cars unloaded in Philadelphia were inspected by the Packaging Service Corp. and the Railroad Perishable Inspection Agency. One test car was diverted and was not inspected at destination.

Laboratory Test Results

The results of individual tests and the main causes of failure are shown in Tables 1 and 2. A typical drop test failure is shown in Fig. 6, and an incline-impact test failure is shown in Fig. 7.

TABLE 1.—RESULTS OF 12-INCH EDGEWISE-DROP TESTS OF LETTUCE CRATES MADE TO VARIOUS SPECIFICATIONS

Crate specification		Moisture condition	Number of drops to failure		Primary cause of failure
Code	Special features				
A	Standard crate	Dry	6		Cross grain in slat
		Dry	9		Wood shear and break
		Dry	7		Cross grain end panel
		Dry	4		Cross grain end panel
		Dry	Av.	6½	
		Moist	9		End open
		Wet	7		Nail pull
		Wet	8		Wood shear in cover slat
		Wet	9		End open, nail pull
		Wet	Av.	8	
B	Standard crate with strap	Dry	10		Wood shear at nails
		Dry	10		End open, wood split
		Dry	10		Slat break
		Dry	9		Wood shear and break
		Dry	Av.	9¾	
		Moist	10		End open
		Wet	7		Cover slat break
		Wet	10		Wood shear at nails
		Wet	9		Cover slat shear
		Wet	Av.	9½	
C	⅓-inch slats with strap	Dry	9		End panel break
		Dry	9		Cover slat shear
		Dry	9		Wood shear at nails
		Dry	6		Wood shear at nails
		Dry	Av.	8¼	
		Moist	7		Cover slat shear
		Wet	5		Wood shear at nails
		Wet	9		Wood shear and nail pull
		Wet	1		End panel break
		Wet	Av.	5	
D	⅓-inch slats, 7/16-inch rails and posts, strap	Dry	9		Slat break
		Moist	8		Cover slat shear
		Wet	7		Wood shear at nails
E	7/16-inch rails and posts	Dry	9		End panel break
		Moist	7		Cover slat shear
		Wet	1		Nail pull

TABLE 2.—RESULTS OF INCLINE-IMPACT TESTS OF LETTUCE CRATES MADE TO VARIOUS SPECIFICATIONS

Crate specification		Moisture condition	Energy absorbed to failure Foot-pounds	Primary cause of failure
Code	Special features			
A	Standard crate	Dry	7,330	Slat break
		Dry	2,980	Slat break
		Dry	3,810	Slat break
		Dry	6,940	Slat break and split
		Dry Av.	5,265	
		Moist	4,780	Nail pull
		Wet	3,310	Nail pull
		Wet	5,810	Slat break
		Wet	2,980	Slat break
		Wet	4,033	
B	Standard crate with strap	Dry	11,000	Slat break
		Dry	16,500	Slat break
		Dry	11,500	Slat break
		Dry	3,260	Slat break
		Dry Av.	10,565	
		Moist	6,990	Slat break
		Wet	5,830	Slat break
		Wet	8,620	Slat break
		Wet	11,500	Slat break
		Wet Av.	8,650	
C	1/2-inch slats with strap	Dry	2,490	Slat break
		Dry	5,810	Slat break
		Dry	5,810	Slat break
		Dry	3,260	Slat break
		Dry Av.	4,342	
		Moist	6,550	Slat break
		Wet	1,280	Wood shear at nails
		Wet	3,530	Slat break
		Wet	2,980	Slat break
		Wet Av.	2,597	
D	1/2-inch slats, 7/8-inch rails and posts, strap	Dry	3,530	Slat break
		Moist	2,050	Cross grain in slat
		Wet	960	Slat break
E	7/8-inch rails and posts	Dry	815	Cross grain in slat
		Moist	9,990	Corner open, rail split
		Wet	262	Nail pull

Relative average test values for the various crates, based on 100 for standard lettuce crates (A), are shown in Table 3. The strapped lightweight slat crate (C) is nearly as strong as the standard crate not strapped (A). The standard crate strapped (B) gave the best performance of all crates. The lightweight slat and head crate with strap (D) and the lightweight head crate not strapped (E) showed relatively low strength based on fewer tests.

The effect of wood moisture content at the time of test is shown in Table 4. Dry and

TABLE 3.—RELATIVE AVERAGE TEST VALUES FOR LETTUCE CRATES MADE TO VARIOUS SPECIFICATIONS, EXPRESSED AS PERCENT OF VALUES FOR CRATE A

Crate specification		Relative average test values		
Code	Special features	Drop test Percent	Incline-impact test Percent	All tests Percent
A	Standard crate	100	100	100
B	Standard crate with strap	125	186	156
C	1/2-inch slats, strap	86	96	91
D	1/2-inch slats, 7/8-inch rails and posts, strap	102	46	74
E	7/8-inch rails and posts	72	79	76

TABLE 4.—EFFECT OF CRATE MOISTURE CONDITION ON RELATIVE AVERAGE TEST VALUES, EXPRESSED AS PERCENT OF VALUES FOR DRY CRATES

Moisture condition of crate	Relative average test values		
	Drop test Percent	Incline-impact test Percent	All tests Percent
Dry	100	100	100
Moist	96	124	110
Wet	72	67	70

moist crates performed about the same. Wet crates showed considerably less strength. Nail pulling was a principle cause of failure only in wet crates, indicating a lessening of nail-holding power for wet wood.

Table 5 shows the comparison between all crates made with $\frac{9}{32}$-inch slats not strapped and all crates made with $\frac{7}{32}$-inch slats strapped. Based on these averages, the standard-thickness slats not strapped show slightly greater strength than the lightweight slats strapped.

TABLE 5.—COMPARISON OF RELATIVE AVERAGE TEST VALUES FOR LETTUCE CRATES MADE WITH $\frac{9}{32}$-INCH SLATS AND STRAPPED LETTUCE CRATES MADE WITH $\frac{7}{32}$-INCH SLATS

Crate specification		Relative average test values		
Code	Special features	Drop test	Incline-impact test	All tests
A, E	$\frac{9}{32}$-inch slats	85	90	88
C, D	$\frac{7}{32}$-inch slats, strapped	94	71	82

The effect of rail and post thickness is shown in Table 6. The results indicate that the 7/8-inch rails and posts do not provide as much strength as the standard 1⅛-inch rails and posts.

TABLE 6.—COMPARISON OF RELATIVE AVERAGE TEST VALUES FOR LETTUCE CRATES MADE WITH 1⅛-INCH RAILS AND POSTS AND CRATES MADE WITH 7/8-INCH RAILS AND POSTS

Crate specification		Relative average test values		
Code	Special features	Drop test	Incline-impact test	All tests
A, C	1-⅛-inch rails and posts	93	98	96
D, E	⅞-inch rails and posts	84	62	73

Packing and Shipping Test Results

Actual packing shed trials on crates for six carloads of lettuce demonstrated the adequacy of the automatic wire tying machine for the strapping job. The machine was installed on the main conveyor behind the lidding machine with no change in existing equipment. The wire tie was effective in obtaining a reduction of approximately ½ inch in cover bulge. The crate girth was also measurably reduced by the strapping.

Carloading was accomplished with no change in procedure from that used for the standard crates not strapped.

Based on information contained in Railroad Perishable Inspection Agency reports, special inspections made for The Wooden Box Institute by the Packaging Service Corp., and publicity released by the U. S. Department of Agriculture, 64 percent as many strapped crates required recoopering service or were delivered in bad order, as was the case for the crates not strapped.

Conclusions

Lettuce crates made with $\frac{7}{32}$-inch slats and strapped were nearly as strong in laboratory tests as standard crates made with $\frac{9}{32}$-inch slats but not strapped.

For additional resistance to rough handling, if such is needed, standard lettuce crates with $\frac{9}{32}$-inch slats may be strapped girthwise with a single strap at the center. In transportation tests this reinforcement effects a reduction of about one-third in the number of crates requiring recoopering service or delivered in bad order.

Vegetable crates may be strapped in packing sheds with automatic wire-tying equipment without interfering with normal production and without change in existing equipment.

High moisture content of wood adversely affects the holding power of slat nails in lettuce crates. Moderate increases in moisture content do not materially affect strength.

Strapping was effective in both the laboratory tests and actual service trials in reducing appreciably the bulge and the girth of lettuce crates.

Discussion

Mr. A. E. Cranston (Cranston Machinery Co., Inc.): Could automatic wire tying machines be used on export packages of vegetables that are now mainly strapped with hand tools?

Mr. Myers: Export packages of vegetables for both military and civilian use are usually double strapped before being loaded aboard ship. This strapping is usually done by the supplier of the vegetables at his warehouse prior to delivery to the dock. For large and recurring shipments, automatic wire tying equipment would undoubtedly be economical. Dry pack vacuum cooled lettuce is now being wire tied for export on automatic machines in the Salinas, California district. If only a few crates are occasionally shipped export from a particular warehouse, manually operated tools would probably be used.

Mr. E. R. Stivers (Package Research Laboratory): If the shipper guarantees size and count of contents, is a bulge pack necessary?

Mr. Myers: Fresh fruits and vegetables tend to shrink during the normal shipping and warehousing period. To prevent the development of a slack pack it is necessary to provide a container that will, in effect, shrink with the merchandise. A bulge cover on the nailed crate effectively follows the contents down as it shrinks and prevents it from becoming loose. If fresh fruits and vegetables are loose in the package they are much more liable to cuts and bruises due to normal handling of the package. The fresh fruit and vegetable industry has always merchandised its products on a unit package basis, and a tight pack with a reasonable bulge is merely a guarantee of full weight. In recent years flat packs have been introduced for certain commodities, and receivers report that although the size and count are supposed to be identical with the standard bulge pack, the packages are often short weight.

Mr. E. G. Stern (Virginia Polytechnic Institute): I wonder whether consideration had been given to selection of the proper nails for assembling the crates?

Thirteen per cent of the drop-tested crates failed in nail pulling. Cement-coated nails were used. The efficiency of cement coating varies with the cement coating material and its application. Were any tests performed on the type of nails used? Provided the cement coating applied gave best possible service, the use of properly grooved nails would have eliminated crate failures as a result of insufficient withdrawal resistance.

Twenty per cent of the drop-tested crates failed in wood shear at nails. Use of a smaller nail-shank diameter would have decreased the occurrence of wood shear along the nail axis since the splitting tendency of the smaller-diameter nails is smaller.

A smaller shank diameter would be justified by use of properly grooved nails since the withdrawal resistance of grooved nails is superior to that of cement-coated plain-shank nails. Possibly, even a smaller number of grooved nails would provide the required holding power than that used for the tested crates.

The statement that nail pulling was a principal cause of failure only in wet crates is indicative of the limited efficiency of cement-coated nails particularly in comparison with the efficiency of properly grooved nails.

In consideration of the observations made, it is suggested that this study be extended to a study which will indicate which size and type of nail provides optimum service. It is entirely feasible that a slightly more expensive nail will result in considerable final savings.

Mr. Myers: Mr. Stern has probably done as much research into the characteristics of various kinds of nails as anyone in the country. I am sure he appreciates the importance of selecting the proper nail for the specific use intended. The Institute Laboratory has made many investigations of various kinds of nails for the assembly of produce and industrial containers. In the series of tests reported on here we are not in the least concerned about the 13 per cent of the drop tested crates that failed due to nail pulling, in fact this might be an indication of the balanced design of the crate. All of these tests were continued to failure. Had none of the crates failed due to nail pull we would suspect that too many nails had been used for balanced design. It is quite possible that with other types of nails having greater holding power, crates of equal strength could be made with fewer nails.

Wood shear failures are of two types—the nail head may pull through the slat or the nailed shank may pull out the end of the slat. To increase the shear resistance, it is necessary to increase the nail head area by using more nails or larger heads, or it is necessary to increase the shank diameter, or use more nails.

In the tests reported here, the frequency of occurrence of these types of shear failures would not seem to indicate that any change was necessary.

In our tests on annularly grooved nails, we found their holding power was much greater than cement-coated nails. These grooved nails also cost more per pound than cement-coated nails. We have suggested their use in many special instances, as for re-usable beverage cases.

Mr. Stern's careful analysis of the test data and his constructive suggestions are appreciated. We will in all future container research consider the use of special nails wherever they seem to offer better container performance and greater economy.

FOREST PRODUCTS RESEARCH SOCIETY

Recent Developments in Containers[1]

W. Butterworth

Timber Mechanics Division, Ottawa Laboratory, Forest Products Laboratories of Canada[1]

This paper describes a style of wooden box with cleats in three-way corner construction; two types of re-use container; and a program of work to develop moulded staves for use in the cooperage industry. The wooden box is very robust and economical of material; its strength allows use of thinner lumber. A number of examples of its use are described. The re-use containers are cleated plywood boxes and incorporate new features for easy opening and closing without the use of tools. The work on tight cooperage is aimed at developing an economical method of moulding standard staves. This will make a barrel demountable and facilitate shipment for re-use.

THIS paper deals with shipping container developments during the past year at the Ottawa Laboratory of the Forest Products Laboratories of Canada. No very sensational or revolutionary developments can reasonably be expected in a field so widely covered as is the construction of shipping containers. They have been used so widely and so long that the bulk of "new" developments must of necessity be small improvements of detail or the adaptation of known principles to new uses.

Style 7-Box

This is a style of construction proposed by the Laboratory in a draft specification for wooden boxes submitted to the Canadian Standards Association. It was designated Style 7. There is nothing revolutionary in this design yet there is evidence, both from actual use and laboratory tests, that this design has merit. It is not in current use to any extent though it is thought that for many purposes the box or one of its modifications would be much more satisfactory than any other conventional style.

This box (Fig. 1A and B) appears superficially to be very like several other variants but it is thought to be better in certain respects than any of these other related types. One such variant (Fig. 1C) was described as long ago as January 1932, in an amendment to the "Ready Reference Manual—Wooden Box and Crate Construction", prepared by the National Association of Wooden Box Manufacturers, Chicago. That style was put forward as a pilfer-proof box and it would appear that the object of the design was to cover the ends of every board in each panel to prevent any board being slid out. Style-7 box is constructed rather for mechanical ruggedness. It will be noted that the design is such that every board is held on the outside by a cleat and on the inside by an adjacent panel, so that the clinch nails have little work to do except hold the panel together until assembly is complete. Fig. 2 also shows another variant in which only the clinch nailing prevents a board being driven into the box by an external blow, although it incorporates the same "pilfer-proof" feature as is shown in Fig. 1C. Either of the boxes shown in Fig. 2 have an advantage over that in Fig. 1C in that the cleats only enter the three-way corner and consequently nails used may be shorter by the thickness of the boards in the panel. Fig. 4A shows clearly how nails or screws are grouped in threes at the end of each cleat, one nail being driven at right angles to and between the other two nails. This arrangement of nails appears to produce great strength as every external force can be resisted by a nail in shear. There is no evidence of nails working loose in transit. This feature can be achieved with either of the boxes shown in Fig. 2, though not with that shown in Fig. 1C.

The features incorporated in this Style 7 box which appear to recommend it beyond all others for heavy or difficult loads are:

(a) The use of the three-way corner throughout.

(b) All nailing is into the side grain of the wood.

(c) The locking effect produced by the cross-nailing at the ends of the cleats.

(d) Boards making up the panels cannot be driven into the box by an external blow.

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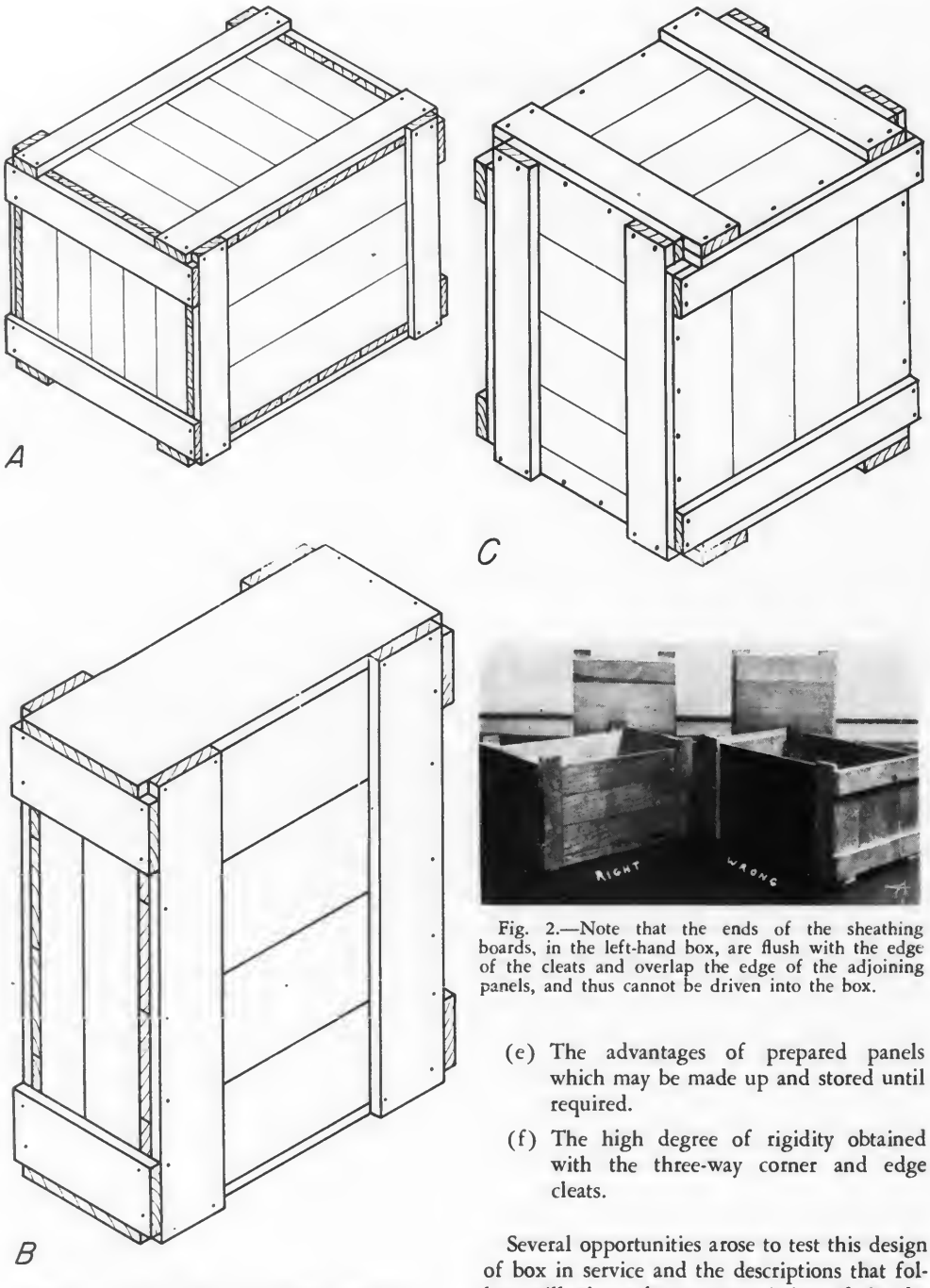

Fig. 1.—*A*, style-7 box; *B*, modified style-7 box; *C*, style-A pilfer-proof box.

Fig. 2.—Note that the ends of the sheathing boards, in the left-hand box, are flush with the edge of the cleats and overlap the edge of the adjoining panels, and thus cannot be driven into the box.

(e) The advantages of prepared panels which may be made up and stored until required.

(f) The high degree of rigidity obtained with the three-way corner and edge cleats.

Several opportunities arose to test this design of box in service and the descriptions that follow will give a better appreciation of the design than any further general discussion.

Stacked Paper Maps

A request for seven boxes suitable for carrying large maps, stacked flat, provided the first opportunity to use the new style box (see Fig. 3). The maps were being shipped to be trimmed

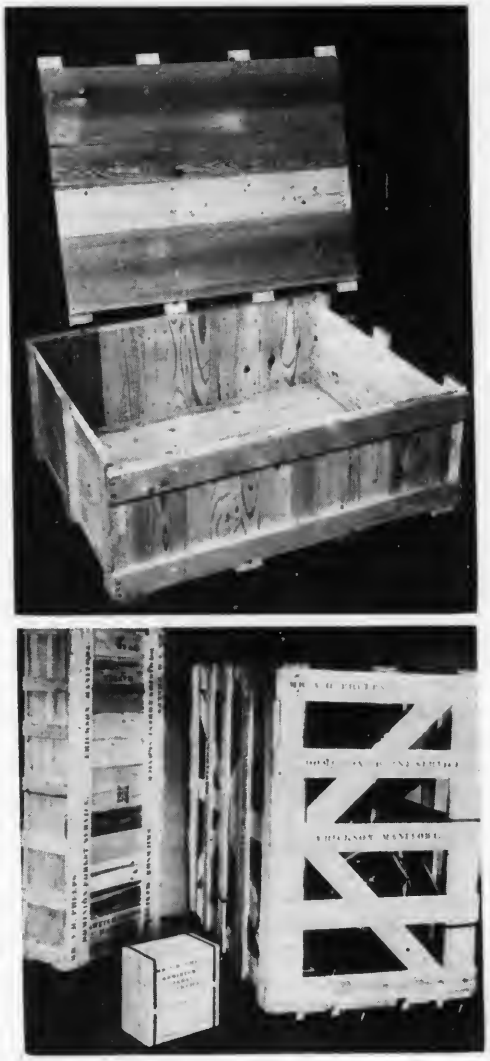

Fig. 3.—Above, box designed to carry flat paper maps. Note top and bottom cleats to prevent bowing. Below, left, box designed to carry electric switchboard.

and bound. Stacked paper is not an easy load to carry. There is a tendency to flex and the stack itself tends to shear or slide. The stacks measured somewhat under 30½ inches by 24½ inches by 12 inches high, and the weight was approximately 270 pounds. A box which could strongly resist the tendency to bowing of the large top and bottom faces, with a consequent straining of the nails, was necessary to carry such a load.

The boxes were constructed from ⅝-inch spruce and the inside dimensions were 30½ by 24½ by 12 inches. Little space was available for packing, but since the maps required further trimming at the bindery, slight damage to their edges would not be objectionable. Panel boards were nailed to the cleats with 1⅜-inch duck-billed clinch nails. The panels were assembled with cement-coated box nails, 2¼ inches through the ends of the cleats and battens, and 2½ inches through the edge cleats into the side grain of the boards of the adjoining face.

A subsequent order for more boxes of this same type was indication of satisfactory service.

Electric Switchboard

An electric switchboard, packed for shipment to northern Manitoba, provided the second practical test for this new style box. Due to the manner in which it had to be supported in the box, this switchboard was a difficult load to carry. It was mounted on two 1-inch pipe standards with elbows at their ends, coupled to floor flanges with close nipples. The switchboard measured just over five feet in length and could only be supported at the extreme ends because of the instruments at the front of the board and the wiring and projecting connections and switches at the rear.

Protection for the switchboard during transit had to provide against the hazards from heavy articles being laid upon the box or the use of a roller across its centre to facilitate moving. The rigidity of the box had to be sufficiently high to prevent sagging of the faces in order to avoid fouling the switchboard.

An advantage of Style 7 when a long box is required, is that it permits the use of shorter boards in the top and bottom faces than do any of the conventional boxes. In this way there can be an economical use of box grade lumber and defects eliminated which would normally be included in the longer boards required for boxes of Styles 2, 2½, 3 or 4.

The box for packing the switchboard (Fig. 3) had inside dimensions of 64 by 24 inches by 10¼ inches, and was constructed with ⅝-inch spruce. The bottom longitudinal edge cleats were 5¼ inches wide to provide for bolting down the flanges of the switchboard mountings. Three ⅜-inch carriage bolts were used to fasten each of the four flanges. To simplify cutting of shooks, the top longitudinal edge cleats were the same width as those for the bottom. As a further precaution against bending, the sides of the box were constructed of two boards 65¼ inches long, stiffened by two edge cleats and five vertical battens. Nailing was in the same general manner as that of the map boxes. The cleats were held to the panel boards by 1⅜-inch clinch nails, and 2¼-inch cement-box coated nails through the ends of the cleats and battens, with 2½-inch nails being used to fasten the edge cleats through the side grain of the boards of the adjoining face. The gross weight of the pack was 270 pounds, the tare weight 80 pounds.

A report from the carrier and consignee indicated that the pack arrived in excellent condition and without even the slightest pulling of nails. However, since such a pack would normally be shipped l:c.l., with relatively greater hazards than in carload lots, further modifications to the design merit consideration. Under l.c.l. conditions the possibility of other articles being placed upon the box would be ever present and might prove disastrous to the switchboard should such an article be heavy and dense and cause bowing of the top of the box. In the original box, due to the nearly exhausted nail stocks, the top and bottom panel boards were fastened to the longitudinal edge cleats with one, instead of three clinch nails. Only the end boards of the panels had three nails. The clinch nails held the panels together until the box was assembled. To compensate for this deficiency, the 2½-inch cement-coated box nails driven through the longitudinal top and bottom edge cleats should have been so spaced (but were not) that the ends of each panel board would receive at least two nails. A much better arrangement would have resulted if, in place of the two 5¼-inch top longitudinal cleats, two 2¾-inch edge cleats had been used with an added intermediate longitudinal batten of the same width. Considerable stiffening would have resulted and breakage of the top boards would have been less likely in the event of some heavy article being placed or falling on the top of the box during shipment, as the central batten would serve to spread a concentrated load over two or three boards.

Glass Bottles

Five 16-oz. bottles containing sulfite waste liquor and shipped to the Research Foundation of Ontario, Toronto, Ont., provided the third application for this style of box. A much less expensive method of packing than the one used would have provided safe transportation. The consequences in time and trouble, should breakage occur, were such that the low cost of extra protection of a single shipment was justifiable. The bottles were difficult to pack since three were round and two were flat, in cross-section. For this reason, a generous amount of Kimpak, 0.37-inch thick, was used to cushion all faces of the bottles. Excelsior rammed in the top of the box transferred the stresses from the relatively weak bottle necks to the much stronger shoulders of the bottles.

The inside dimensions were 7 inches by 7½ inches by 8½ inches deep, and the box was made up from ½-inch lumber. Panel boards were fastened to the cleats with 1⅛-inch clinch nails. Panels were assembled with 1¾-inch cement-coated box nails. Nailing was at the three-way corners only. The gross weight of the box was 17 pounds. The advantages of the Style-7 box for this purpose were its symmetry and equal strength in all directions. Ample protection was afforded to the contents.

Gallon Tin—Class-B Poison

A modified version of the Style 7 box was used for packing a gallon tin of Class-B poison. This box differed from the normal Style-7 box in that one inside dimensions, 4⅝ inches, was so small as to make it unnecessary to use both sheathing and cleats at the ends. Had both cleats and sheathing been used, the ends would have been, in effect, a 2-ply cross-grain construction. Such a box would have a much stronger end than required and one that would be out of balance with the remainder of the box. This modified design would have special merit for boxes where one dimension is small

enough for one piece of board conveniently to make each of two panels or perhaps two boards, suitably joined. The application of the design here discussed is not considered as an ideal one, but it does point to possibilities for use. This modified design is particularly adaptable to the requirements for a container for plate glass and other sheet material. It is suitable for fine panelling, polished metal sheets and other material having a high surface finish, and corrugated metal, composition board panels and similar material requiring protection against crushing. For extremely heavy articles, such as flat tombstones, the narrow faces of the box might well be made of 2-inch by 4-inch by 6-inch, or other suitable widths and thicknesses.

The box for the Class-B poison shipment had inside dimensions of 4⅝ inches by 6⅝ inches by 12 inches. Cleats and sheathing were of ½-inch stock, and nailing followed the usual pattern for a Style-7 box. The pack weighed 25 pounds gross and 4½ pounds tare.

The modified version of the Style-7 box will be known as Style 7A.

Precision Machine Tool

A wood-planer head, with attached direct drive motor, had to be returned to the maker for repairs. Shipment required a container which would provide adequate protection and insure that shaft alignments were not upset. A Style-7 box was constructed into which the unit fitted snugly end to end. Lateral and vertical movements were prevented by blocking. Inside dimensions of the box were 37¼ inches by 10¾ inches by 10¾ inches. The box was constructed throughout from ¾-inch stock. Fig. 4 clearly shows that the box was constructed in the conventional manner. There was one difference in the assembling of the panels, in that the top was screwed on to provide easy access and prevent damage to the container. It was intended that this box be again used for returning the repaired unit to the laboratory. All nailing of bottom, sides and ends was done with 3-inch cement-coated box nails.

By a simple, yet effective method, the unit was properly located in the box. Two hardwood blocks—grooved to accommodate the 1-inch by ⅛-inch splines in the motor and outboard bearing housings—were bolted to the housings through the bolt holes provided for

Fig. 4.—Box used to pack planer head. Above, interior view showing side blocks used to hold unit down. Center, box ready for shipment. Below, box after round trip. Note reversal of top and marks left by nail puller along lower side.

mounting the planer head and motor to the machine table. A wood strip ¾-inch by 1¼-inches by 9-inches was nailed to the box bottom under the ends of each block to provide clearance for the lower budge of the motor. The blocks for the motor bearing were 1¼-inch by 10¾-inches by 6-inches, and 1¼ inches by 10¾ inches by 3 inches for the outboard bearing. This arrangement supported the unit in its normal operating position. The whole assembly was held down in the box by four blocks, cut from cleat stock, and bearing against the upper surface of the mounting blocks and the underside of the lid when the box was closed. These blocks, nailed to the sides of the box, may be seen in Fig. 4. The gross weight of the boxed unit was 262 pounds, and the net weight 227 pounds. Because of the eccentric load, the sling point was marked with a black line and stencilled "Sling Here" on the sides and top. The box was shipped by rail to Galt, Ontario, and was used to return the repaired unit to Ottawa. The round trip was one of approximately 600 miles made under l.c.l. conditions. In addition, truck handling was necessary to and from the freight depots. After return to the Laboratory, the container was examined for failures.

Examination first disclosed that the sling marks on the sides and top did not coincide showing that the top had been reversed end for end on the body of the box. Slinging at the Laboratory showed the centre of gravity to be at the sling line on top of the box. The conclusion was that the unit had been returned to the box reversed end for end from its original position (Fig. 4). When the box was opened all blocking was found to be in proper position. Evidence of the use of a nail puller to remove the bottom explained the above. Apparently the position of the bottom was reversed end for end when it was replaced, making necessary the reversal of the unit and the box top which carried a pad on its underside to bear against the motor. In replacing the bottom, 2½-inch common nails were used.

Damage sustained by the box was located at the end occupied by the motor on the return trip. The boards were cracked mid-way between the cleats. This more than likely was the result of a severe end drop, as might occur when dropped off the end of a truck. The nature of the wood failure indicated a certain amount of brashness caused by the presence of some compression wood. Examination of the box showed that the end bolts of the motor had sunk into the end boards until the motor housing rested snugly against the wood immediately behind the cleats. This indicated that a further breakthrough was prevented by the cleats. Marks left by the motor at the opposite end of the box show that the failure occurred on the return journey.

The original nailing held remarkably well, and there was no evidence of nail pulling. Even the 2½-inch common nails showed no evidence of pulling, though they were easily removed for examination. This points to the efficiency obtained by cross-nailing, which mainly places shear stresses on the nails and reduces, if it does not entirely eliminate, tension on the nailing. Fig. 4 shows the condition of the box after the return journey.

This failure of one end, which opinion at the Laboratory believes to have been caused by excessively rough handling, points to an unbalanced construction. Further consideration of the design shows the need for a better balance of strength of the sides, top and bottom, compared with the strength of the ends. A better absorption of the end to end thrust would be obtained if the thickness of all members were reduced to ⅝-inch and two inside cleats added at each end to compensate for this reduction in lumber thickness. These cleats should be fitted inside directly behind, and parallel to the end panel cleats. These inside cleats would take the load of the motor housing and leave the ventilator at the end of the housing free from contact with the end panel boards.

With this style of box in mind, but using plywood in place of boards for the panels, two re-use containers were developed. These are thought worthy of description as they may have wider application than the specialized fields for which they were developed.

Re-Use Containers for Parachutes

Fig. 5 shows a box designed for shipping parachutes. It would be used in the first instance for shipping the parachutes packed ready for use, and on this trip the box must admit of some kind of seal that would assure the recipient that it had not been tampered with. In the

Fig. 5.—Parachute shipping container. Top, box closed. Center, method of inserting lid; below, box after test.

second place, it would be used to ship a parachute that had been opened, back to the factory for examination and expert refolding. For this latter purpose, it is essential that the box be absolutely smooth finished inside and out so that nothing can snag the parachute fabric. This particular box measures 24¼ inches long by 14¾ inches wide by 15¾ inches deep externally and is of ¼-inch, three-ply plywood. The cleats are ½-inch by ⅞-inch birch and the centre battens across the bottom and top are ½-inch by 1⅞-inch birch. The box weighs 13 pounds and the gross weight with main and reserve parachute is 50 pounds.

The box shown is fastened by two screws at each end of the centre batten of the lid. The lid is hinged under this batten, the hinge being formed of a strip of canvas glued to the plywood. Fig. 5 shows the method of inserting the lid. The lid is folded sufficiently to allow the ends to pass beneath the top cleats of the box and is then shut down. It may be fastened by screwing as shown, or if filler cleats are provided on the sides, a single girth strap will provide a secure fastening. Another method would be to recess hinged hasps into the underside of the centre cover batten. The hasps are bent to fit around the top cleat on the side and close over a staple fixed to the side panels. With this method of fastening a lead seal on a loop of wire can be used.

Fig. 5 shows the box after it had withstood 60 drops in the 14-foot hazard machine and an end-to-end compression load of 11,000 pounds. The compression load was applied in this direction as, on account of the proportions of the box and the position of the lid, this is the weakest direction. The hazard machine test was conducted with a box loaded with main and reserve parachutes but was somewhat more severe than is to be expected in service as webbing straps to retain the parachutes in position had not been provided. On the result of these tests it is thought that $\frac{3}{16}$-inch plywood will be adequate but the cleats are about as small as is practicable to hold the screws used for fastening the panels together. The use of the thinner plywood would slightly reduce the weight of the box, which is desirable as air transport may at times be used.

Outboard Motor Box (Field Service)

The other re-use container is of a heavier and more robust construction as a more difficult load is involved and there is no necessity of air transport.

For the use of field parties operating during the summer months in the bush lands of Northern Canada a special box was required to ship outboard motors. The box is used to ship the motors in spring from headquarters in Ottawa to the party's base of operations at rail or road head. Here the box must be opened without tools as these are packed with the motor tool kit inside the box. In the fall the motors are re-packed for return to Ottawa for overhaul and winter storage. The tool box only is carried on expeditions, but in view of the fact that many seasons' service is required and the risk of exposure to humidity is always present both tool box and main container were treated with successive coats of spar varnish, undercoating and enamel paint.

Fig. 6 shows an isometric drawing of the box evolved for this purpose, and Fig. 7 shows three views of the box when it is packed with a 5 hp. outboard motor. The panels are 1/4-inch plywood and all cleats 1/2-inch by 1 7/8-inch hardwood.

The motor is attached by its normal mounting bracket to the mounting block (Fig. 6 part No. 21) and is then placed in the box so that the propeller shaft housing rests in the crotch in part No. 20 and the mounting block slides down between battens No. 12 and rests on the tool box rails, No. 13. Side to side movement is prevented by the pressure block No. 14. The holding-down block is then placed on top of the mounting block and this bears against the underside of the lid where it is reinforced by one of the battens No. 9. The lid is in three sections. The two end pieces (part No. 4) slide into position with their ends under the end cleats (part No. 8) and the small centre lid hinges into position and is held by the hasps which are bent to fit snugly under the side

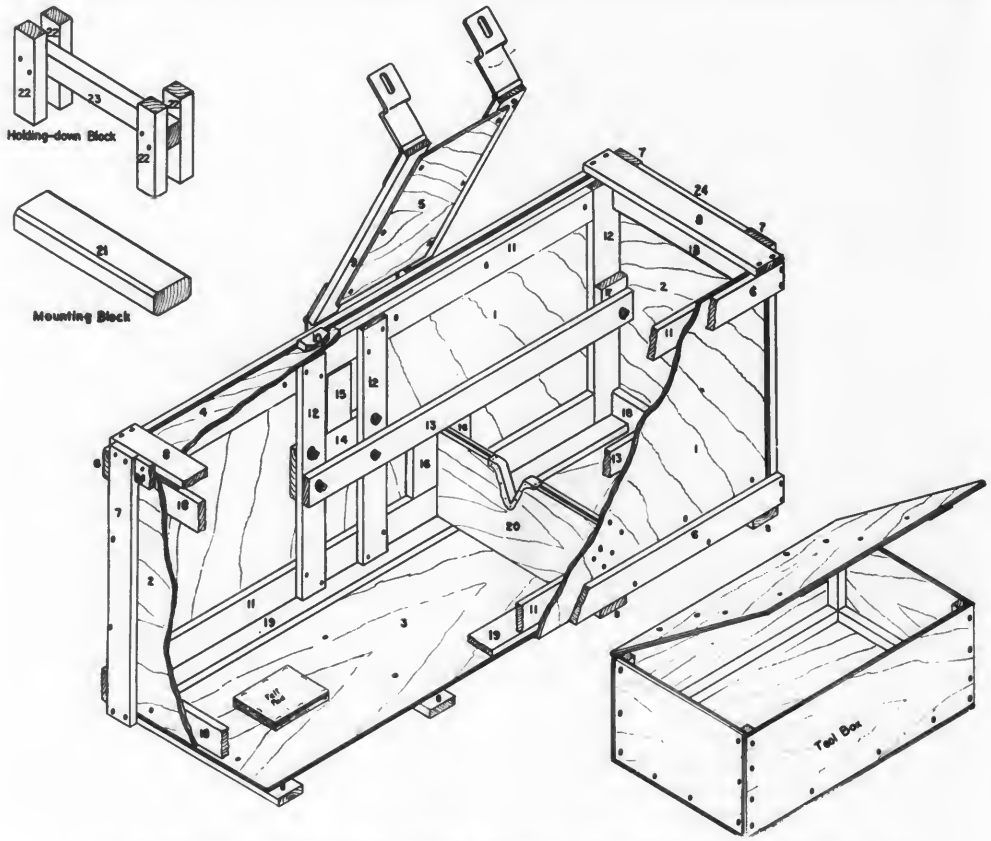

Fig. 6.—Plywood case for winter storage and seasonal shipment of Johnson outboard motor.

Fig. 7.—Box for outboard motor. Top, closed. Center and bottom, views with top removed, showing motor in place.

cleats (part No. 6). A hardwood wedge is used to fasten each hasp to its staple and a wire seal (easily broken by twisting by hand) used to prevent the wedge working out in transit.

The loose parts of the box are anchored to the box by suitable lengths of safety chain.

The tool box is constructed to rest on the rails (part No. 13) and it is prevented from moving by the battens No. 12 and the stop No. 17. The top of the tool box rests against the underside of the lid and its bottom edge rests on the lower part of the motor mounting bracket thereby helping to hold the motor securely in position.

Moulded Staves for Tight Cooperage

A new development in a different direction, currently being examined by the Laboratories, is in an endeavour to reduce the cost of tight cooperage. It would seem that the most promising fields in which to reduce costs in cooperage are those of raw material, labour costs and ease of return shipment for re-use.

The raw material in present use is very expensive as only clear lumber free from defect can be used. If a process can be found to render lower grade material usable it could have far reaching effect in the industry, especially if it also resulted in the utilization of waste material from other processes.

Labour costs are high because of the multiplicity of operations involved in conventional cooperage and the fact that selection and assembly of a set of staves is an expert operation. These costs could be materially reduced if a standard stave could be produced cheaply. Standardization is not practicable at present owing to the need for maximum usage of very high grade material.

Standardization of staves would have a secondary effect in making a barrel demountable so that empties returned for re-use could be more economically transported. This would make tight cooperage more attractive to the user.

The Laboratories are now working on a method of moulding barrel staves of standardized pattern. Various raw materials of forest origin are being investigated as well as the important matter of cheap mould production. There is considerable hope of success in this investigation.

It is hoped that this will give a picture of the kind of work being done at the Ottawa Laboratory of the Forest Products Laboratories of Canada to serve industrial needs. Work described arose mainly from requests for a solution to a specific problem. Thus, it is impracticable to forecast the kind of problems that will receive attention in the near future.

APPENDIX—Testing

In support of the contention that the Style-7 box is more rigid than boxes of any previously accepted styles, a limited program of tests was undertaken. It has been accepted that a Style-2 box is more rigid than Styles 1, 4 and 5.

Two Style-2 boxes were made in accordance with C. P. C. 11, page 12, table 1, for weight of contents 101 to 250 pounds. Group 1 lumber was used. The end boards were $\frac{5}{8}$-inch thick with cleats $\frac{5}{8}$-inch by $2\frac{3}{8}$ inches. The sides, top, and bottom were $\frac{9}{16}$-inch thick. Inside dimensions were 24 inches by $16\frac{1}{2}$ inches by 12 inches. The boxes were nailed with $2\frac{1}{2}$-inch cement-coated box nails and reinforced with two $\frac{1}{2}$-inch nailless girth straps. Two Style-7 boxes were made to the same dimensions with $\frac{9}{16}$-inch lumber of the same species. The two cleats on each face were $\frac{9}{16}$-inch by $2\frac{3}{8}$ inches. Cement-coated box nails 2 inches long were used to nail the cleats to the cleats, and $2\frac{1}{4}$ inches long to nail through cleats and boards into the edges of adjacent panels. The boxes were not strapped, as it would not be normal practice to do so, since filler cleats would be necessary to prevent the strapping from spanning gaps. The standard of workmanship of the Style-2 box was excellent, but slightly inferior in the Style-7 boxes, and there were more defects in the lumber, such as knots, worm holes, and small pockets of decay. Some of the cleats of the Style-7 boxes had been cut a little short, making it necessary to nail nearer to the end than is normal.

After testing, a Style-7 and a Style-2 box were re-coopered. All nails were pulled, panel boards were fastened together with corrugated fasteners, and the boxes reassembled with new nails. In nailing, previous nail holes were avoided. (At the corners of the Style-7 box it was necessary to reverse the usual nailing practice and drive one nail through the ends of the cleats and two nails through the sides of the cleats.) Two additional Style-7 boxes were then made and corrugated fasteners were used between the panel boards. The results of tests on these boxes are shown in Fig. 8.

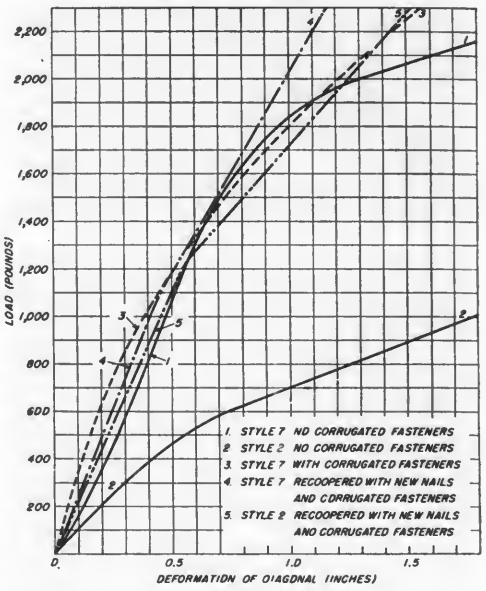

Fig. 8.

The boxes were tested in diagonal compression, generally in accordance with American Society for Testing Materials procedure, but—in order to allow for more load/deflection observations—at $\frac{1}{8}$-inch per minute crosshead speed instead of $\frac{1}{2}$-inch per minute. The lines drawn indicate an average load/deflection curve for each type of box. The greater stiffness and strength of a Style-7 box is apparent.

Discussion

Mr. E. W. Wellwood (Canadian Forest Products Ltd.): Have any tests been made on boxes constructed of hardboard and if so, what have been the results?

Mr. Butterworth: We have not, to date, done any work on this.

I have been asked, "What lumber should be used in the construction of the style 7 box?" The choice of lumber for this type of box is governed by exactly the same considerations as apply to any other style of box. This is to say, the most readily available material of a grade suitable for box construction by the same standards as have always been held desirable.

FOREST PRODUCTS RESEARCH SOCIETY

Loss and Damage in Transit in Relation to Shipping Containers—Viewpoint of the Carrier

Albert L. Green

Special Representative, Freight Claim Division, Association of American Railroads

Merchandise undergoes many hazards before actual transportation begins. Numerous measures can be taken to deal with these hazards. Loss and damage claims claim a substantial fraction of gross railroad revenue and figure definitely in rate making. Causes of damage in transit include slack loading, inadequate interior packing, and inadequate container design. The value of improved packaging and handling efforts by both railroads has been repeatedly demonstrated.

Introduction

I SUPPOSE that the relationship of shipping containers to the common hazards of rail transportation has not been established precisely, nor even approximately, either by laboratory testing or inspections of the condition of packaged articles when received by the consignee. If anyone in the audience or any reader of this paper believes he has a dependable answer, I would like to hear from him as I, myself, would be very much interested in learning what the relationship is between the package and the ordinary or average risk of loss or damage in transport. By no means does the question have to go totally unanswered because most everyone who has had extensive experience with the packaging of commodities in general or with the packaging of products made by his company has derived from the "school of experience", or from laboratory research a reasonably satisfactory answer to the question: How much protection must be afforded to safeguard the product against the risks inherent in the handling of goods in the factory, in carriage to the railroad station or in loading in the car; en route and in the course of delivery, warehousing and distribution?

Pretransportation Hazards

Shall we consider first examples of the damage risks before transportation begins. Observations were made by a committee appointed by one of the largest merchandise houses to improve its operation. The committee reported in part:

"Unwarranted damage not traceable to crating, carrier operations, or manufacturers' defects may be the result of either carelessness or lack of proper instructions. In an effort to determine the most common causes of such damages a survey was recently conducted in a number of our operations. This disclosed that in many cases such damage was attributable to improper car unloading methods and warehouse handling. Following are some typical cases observed during the survey:

(1) While unloading merchandise stacked two or three tiers high, employes stood on lower tiers to reach the items above. The combined weight of the person and the merchandise being removed often caused the light plywood or fiber board surfaces of the case on which he stood to depress or even collapse, thus damaging its contents.

(2) Crates containing such items as stoves, refrigerators, washing machines, etc., were dropped from upper tiers to lower ones or to the car floor. Drops from heights such as these are much greater than those for which the containers were designed. This often caused a complete break-down or distortion of the boxes or crates.

(3) Broken crates were stacked in warehouses resulting in additional damage to merchandise.

(4) A refrigerator was dropped to the floor of the car with such an impact as to tear the entire porcelain liner from its fastenings.

(5) Merchandise was badly scratched due to failure to properly remove the steel straps used in bracing cars.

"By observing the following safe handling measures employes will both protect themselves from possible injury and prevent damage to merchandise:

(1) When it is necessary to stand on crates or cases of lower tiers in order to reach merchandise from above, always place a plywood platform (preferably 3/8-in. sheathing-fir plywood) on the lower tier. This will not only insure safe footing, but will prevent the container on which you are standing from depressing or collapsing, since any excessive weight will be more evenly distributed.

(2) In lowering heavy cases from an upper tier, skid them to the lower level by means of a plank. This will better enable you to control the speed of descent, and thereby prevent unexpected drops which can cause injury to fellow workers as well as damage to the merchandise.

(3) Broken crates are to be repaired before being stacked. Otherwise they may further collapse and topple to the floor.

(4) Steel strapping used in bracing cars should be completely removed. Pieces left in cars can cause injuries to employes or scratch merchandise.

(5) Where help is necessary to handle heavy items, never attempt a 'solo'.

(6) Make certain that you have a firm hold and that the lift or pull be gradual.

(7) Merchandise should not be dragged across the floor. Use a two-wheeled truck, a dolly, a pallet truck or other aid.

(8) Never use a two-wheel hand truck as a battering ram. The lip of this truck has been a source of much damage. Set the item down. Then "walk" it in place.

(9) Be careful when setting items in place for storage or uncrating.

(10) Aisles must always be kept clear to allow sufficient room to move items to their storing place without bumping into other merchandise that is stored on either side of the aisle."

Importance of Claim Reduction

Why is an effective claim-prevention program so essential to railroad and shipper welfare? Why is it so essential to the shipper's interest that he know at all times what loss and damage of his shipments amounts to? Of course, there are several answers. One is that the claim expense comes from earnings and obviously is considered in rate making. In a real sense the shipper pays his own claims—at least through rates he provides the money. In 1948, loss and damage claims cost U. S. railroads $130,656,024, or $1.61 of each $100 of gross freight revenue. In 1949, the cost was $109,202,227, which equalled 25 percent of the total net income of all Class 1 railroads, and for the first half of 1950, $42,534,259, 30 percent under the first half of 1949. Out of revenue for the 1950 period $1.20 of each $100 was paid for claims. These figures are the strongest argument I can present for accelerating the prevention effort by railroads and shippers alike. Illustrating what has been done —and what can be done again—in recent non-war years the revenue percentages taken by claims hovered around one-half of one percent.

Causes of Damage

Now let's turn to some of the recognized damage risks incidental to transportation. One of the cardinal principles of loading cased goods is to make certain that all possible slack is taken up in the load. Comparisons of tight vs. loose loads of packaged fresh fruits and vegetables, for instance, have shown that the damage increases in substantial accordance with the amount of slack or looseness in the load which was not taken up by the shipper at the time of loading. This principle also applies to commodities such as canned foods in fibre boxes where damage in a well prepared car in good condition may be virtually eliminated by very tight loading under the bonded-block method provided the box fits the cans very tightly and is of good quality and properly

sealed. To the other extremity is the risk of over sized boxes being used and careless loading resulting in slack space of a foot or two opening up in the load, and in such instances, the compression in the case itself and the space opening up in the load result not infrequently in damage running into hundreds of dollars in a single car.

There are also crushing forces created by the switching of cars in yards and terminals, slack action in the trains and vertical vibrations of the car common to present-day high speeds which must be guarded against by adequately protective bracing or blocking of the load (if such is needed) or by strapping sections of the load together so they may slide on the car floor under switching impacts and thus absorb the shock. In other words, in loads which require some form of buffer or bracing there must be a "resisting give" in the load which will be sufficient to serve as a cushion of the shocks which cannot be avoided.

Then there are other damaging shocks which must be protected against such, for example, as the handling through the freight house, to and from motor trucks, in warehousing and in the final delivery to the retailer. I cannot go into this in detail but perhaps it will suffice to cite one example of what happens when an article is dropped—a drop that many would consider quite safe. An impact register was fastened to the end of a crated enameled stove. The end of the stove was dropped 12 inches to the floor and the register showed that the force of the impact was about equal to what it might have been in a freight car coupled at a speed of 12 mph. At least that was the record on the register tape.

In an L.C.L. car of miscellaneous merchandise fragile articles must be cushioned and protected inside the container and the container must have sufficient resistance to compression so that it will adequately protect its contents. The fact that over the last five years claims for concealed damage, i.e., damage which is found after the containers are opened by the consignee, averaged about $13 million a year, is, I think, evidence enough that fragile articles are not sufficiently protected inside the container.

Let's see what's wrong here. Is it not likely that department stores, for illustration, receive merchandise such as end tables, coffee tables, etc., right along from certain sources, some coming in damaged repeatedly—often interfering with sales schedules—whereas the tables from other sources are seldom, if ever, damaged in transit. Probably all of this line of goods is shipped f.o.b. factory, the shipper seldom hears anything about damage and unless the customer or the railroad reports the nature and apparent cause of the damage to the shipper, he may go right on year in and year out neglecting to cushion and protect his product in the container so it will have a reasonable chance of a good-order delivery. From our broad experience with these concealed damage claims, we know that there is a positive relationship between the method of the packing and the damage experienced.

Some Demonstrations

One or two illustrations can be cited in the field of perishable freight. In 1949 inspections of 1803 cars of cantaloupes disclosed an average damage of 9.9 packages per car, i.e., packages that could not be restored to good sales condition, in 1766 cars of crates with regular slats of dimensions $\frac{3}{8}$ by $1\frac{7}{8}$ in. Whereas in 37 cars, crates with experimental slats measuring $\frac{3}{8}$ by $2\frac{3}{8}$ in., the bad-orders were reduced to an average of 2.8 per car. Also in 1949, demonstrating the effects of improved loading, the so-called "divided load" used in the loading of 11,951 cars produced average bad-orders per car of 37.9, whereas in 31 cars with the crates loaded on end, the average bad-order was 7.9 per car. And in the movement of Mexican tomatoes, we have a record that shows that in the 1943–44 season, there were on the average 46.0 bad-orders per car, but in the 1948–49 season this figure had been cut to 16.9 bad-orders per car, due partly to improved shook, better nailing, and the limiting of the height of the load to seven layers.

Several years ago, claims for damage to furniture exceeded $10 million a year. The railroads were convinced that substantially improved packaging was needed. After an extensive study, in which furniture manufacturers participated, an agreement was reached with the industry whereby the packaging was greatly improved. Some 55 individual packages were

defined and specified in the Freight Classification and largely as a result these claims for the first half of 1950 are running at the rate of about $6 million a year despite higher values and largely increased production. It is quite likely that the railroads are giving better attention to the handling of furniture but in the main this improvement can be credited to improved packaging—another demonstration that there is a definite relationship between the protective values of containers and the ordinary risk of transportation.

Another illustration is the voluntary agreement that was reached by the glassware manufacturers whereby drop tests were put in the Freight Classification. Probably without any overall increase in the cost of packaging to the industry claims on these articles have been reduced considerably and we were recently advised that the U. S. Potters Association has agreed to publication in the Classification of the same drop tests (based on performance) for chinaware and crockery.

Perhaps the most outstanding example of achievement in the way of improving the damage experience is to be found in the National Safe Transit Program sponsored by the Porcelain Enamel Institute. While it is true that this program has not been generally adopted by the makers of household appliances those firms which did adopt it are able to show a large reduction in transportation damage during a period of greatly increased production. This program, as most of you know, is a purely voluntary one on the part of the trade and it calls for certain test procedures applied to the packaged product at the factory which are adjusted to the expectable damage risks in distribution and where those tests have been faithfully followed the shipper is able to "stop the loss before it occurs".

Time does not permit me to even briefly sketch the employee-training programs followed by the railroads directed to more careful handling of freight and cars, but I would like to say that each railroad has its own department specializing in loss and damage prevention; inspections and investigations and reports to shippers are made by the several weighing and inspection bureaus and this Association has a staff of claim-prevention specialists in its Freight Claim Division devoting all of their time to discovering the causes of claims, and how those causes may be corrected; attached to the Freight Claim Division is a National Freight Loss & Damage Prevention Committee which coordinates and directs the activities along these lines and we also have a corps of packaging and loading engineers in our Freight Loading & Container Section which, after due investigation and conference with shippers, prepares pamphlets showing how freight should be packed and loaded for safe transportation.

Value of a Container Testing Program

The most effective way I can think of for determining whether freight is adequately protected for transportation is to have the packaged product examined and tested in the commercial laboratory. The laboratory technicians have not yet been able to lay down a series of tests for all articles which will develop a positive remedy for damage. Tests differ according to the requirements of the particular article tested—it may be a series of falls in a revolving drum, it may be an incline-impact test, it may be a drop test or it may be a critical examination of the protective merits of the container. But whatever test is applied the laboratory must duplicate as closely as possible the stresses and strains which bring about the damage occurring in transit. If a table is being tested and the damage complained of is a repeated breaking of the legs and the laboratory does not break legs, the tests are futile. It, therefore, follows that the laboratory must apply just the right stresses and strains to break legs before the table is on the road to changing the packaging to the point where legs are no longer broken under impacts like those sustained in handling and in transit.

Yes, there is a relationship between packaging and transportation hazards and there are available to all shippers simple and economical means for discovering and correcting whatever may be amiss with the packaging, handling or loading and where these means are availed of, it has been our experience that there is no article, however fragile it may be, that cannot be carried with a relatively low risk.

Value of the Carriers' Effort

I believe that your society is genuinely interested in better utilization of forest products such a large proportion of which are consumed in the manufacture of both wood and fibre shipping containers and that you are interested in having those products given the best possible service; however, I am not certain that the members realize that the efforts of the carriers to reduce loss and damage claims is really a service to the public and not merely an effort to reduce operating costs. In this connection, I feel that too few people realize that packaging is one of our major industries. The total value of its products runs into billions of dollars annually. Nor is it realized that packaging plays a part in practically every industry or business. It is difficult to name a product of industry or agriculture that has attained its full value and usefulness at the point of production. In order to serve its intended purpose, it must reach the consumer in usable condition, and that is where the container and the transportation facilities come in.

If there is any information that we have which would be of interest to any member of this Society or if you have a damage problem you don't know how to solve and you think we could be of assistance, please communicate with us at 59 E. Van Buren Street, Chicago 5, Illinois, and we shall esteem it a privilege to help you if we can.

Discussion

Mr. A. Elmendorf (Elmendorf Research, Inc.): Referring to a specific type of shipping container used in great volume, namely, the egg case, can you tell us whether the Association of American Railroads has compiled any statistical data comparing the claims against loss of the wooden egg case with those of the fiber container?

Mr. Green: The association has not collected claim data to show the difference in protection to eggs afforded by the fibre box compared with the wood box. Extensive tests on both types of box made by the U. S. Forest Products Laboratory some years ago showed that the fibre box, as then constructed, developed substantially less resistance to crushing forces than the wood box. This was especially true of fibre boxes conditioned to simulate storage conditions. The construction of the fibre box since then is believed to have been somewhat improved. However, one of the factors that may be partly responsible for damage claims increasing from $3 or $4 per car to around $100 per car originated in the last few years is the largely increased use of the fibre box. My personal opinion is, that a further study should be made of the fibre box, by use of instruments to measure the effect of vertical and horizontal shock in transportation, and in laboratory, to find out whether the fibre box as presently made affords adequate protection.

Mr. B. L. Grondal (College of Forestry, University of Washington): I had intended to ask about the $13 million dollar loss in concealed damages that the railroad sustained in 1949, and what shippers and receivers could do to prevent these losses, but it has been partially answered. However, having seen a costly machine unpacked when a casting was broken because a concealed bolt was attached to a cleat nailed to the crate (the railroad paying the damage claim), has it occurred to your packaging engineers to call up the CIO or the AFL to send a man with a crowbar to open a "good" crate.

Mr. Green: Claims paid for concealed damage over the last five years averaged about $13 million a year. One of the main causes is failure to provide adequate inner fittings that cushion and protect fragile articles inside the shipping container. Packaging studies made by mail-order houses, box-makers and others indicate that well designed inside packing is almost a final answer to this sort of damage. If large department stores, for example, made a practice of comparing the protective merits of inner packing materials and their application where the same or similar articles from some shippers are damaged repeatedly, and the products of other shippers consistently arrive in good order, informing the shipper of his failure to pack properly very many of these claims would be wiped out. As most merchandise is sold f.o.b.

factory and almost all claims are filed by consignees, shippers often assume, in the absence of complaint, that their goods are well packed, when the contrary is true. Box manufacturers can solve most any problem of this kind if called upon for assistance.

Mr. S. D. Soule (Wooden Box Institute): If loss and damage claims are reduced by 50 percent by better containers, better loading or bracing, how long would it take for this savings to reflect back to the shipper in the form of reduced freight rates for the particular commodity in which this saving was made.

Mr. Green: It would be difficult to prove in a given case that a 50 percent reduction in damage claims resulted solely from better containers or loading. Other factors might have changed. Under the law, it is the shipper's duty to pack and load his shipment so it will carry safely in normal transportation. Damage claims are a cost factor in rate making.

Question: What is the experience with drop tests of packaged products made at the factory before shipment? I notice the Freight Classification specifies drop tests for glassware.

Mr. Green: There has been a large reduction in damage claims on glassware since the manufacturers began to use drop tests two or three years ago, and particularly since such tests were put in the Classification. It is really a test based on performance. Mail order houses, for example, have employed such tests on all sorts of fragile articles, and have learned how to keep damage down to a low point. Drop tests for chinaware, pottery, earthenware, etc. will be docketed for public hearings shortly.

This type of testing and other tests are included in the National Safe Transit Program of the Porcelain Enamel Institute. This program is unqualifiedly endorsed by all carriers. Large manufacturers who have adopted the full program have reduced transit damage substantially.

Loss and Damage in Transit in Relation to Shipping Containers (Viewpoint of the Container Manufacturer)

J. M. Ladd

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Damage to goods in transit has increased tremendously in the past ten years, but can be reduced by cooperation among the shippers, the carriers, and the container manufacturers. The latter group can contribute to this program by a number of services herein outlined, and as a group have established projects now showing beneficial results.

Introduction

THE economic loss occasioned by damage to goods in transit is of such magnitude that it should be of deep concern to all of us. Because of its importance, the three industrial groups most directly concerned, namely; the shippers, the carriers and the container manufacturers, are all represented by papers at this meeting. It might naturally be assumed that the carriers and the shippers have the most at stake in reducing loss and damage, but the container manufacturer has an interest equally vital. Satisfied customers are the prerequisite for repeat business, and only satisfactory shipping performance will build for us the good will necessary for any industry. Each of the above mentioned groups has a definite responsibility to perform to bring about a reduction of damage to goods in transit.

Scope

Since there are so many different types of containers ranging from paper bags to steel drums, it would not be practical to herein discuss individual containers. Each has its own advantages and disadvantages and will perform well when used in the manner for which it is intended, and the relation of the manufacturers of each to the problem at hand is very similar. Neither will we attempt to herein present detailed statistics concerning transit loss since the carriers are better qualified to present these figures. Suffice it to say that the number of railroad damage claims presented annually climbed from 2,380,143 in 1940 to 4,890,601 in 1948, with damage jumping from $21,059,149 to a staggering $135,390,664 during the same period of time. This paper, therefore, is intended to outline the methods by which the container manufacturer can promote safe shipping, and it will discuss some of the steps which members of this group have taken to assure fulfillment of their part in the program.

Functions of the Container Manufacturer

The types of assistance to the shipper which can be offered by the container manufacturer might be itemized under six headings: 1. Proper container design. 2. Compliance with existing specifications. 3. Correct manufacture. 4. Instruction in proper usage. 5. Advice in carloading. 6. Inspection of shipments at destination. These are of such importance that each justifies further discussion.

Proper Container Design

This is the initial step to insure safe arrival of the product and is of primary importance. For most items, shipping containers should be engineered to do the specific job for which they are intended since the use of second-hand containers or stock sizes frequently contributes to shipping losses. For this design work, many container manufacturers provide laboratories which are staffed with qualified packaging engineers and equipped with various package testing devices. It is the laboratory's responsibility to establish container specifications for specific items which will assure safe arrival despite normal shipping hazards. Full cooperation from the customer is needed of course. Such cooperation will prove to be mutually beneficial. It frequently happens that in the original engineering of a product, little or no thought is given to transporting it; whereas, if shipping is duly considered, the unit may possibly be slightly altered with consequent savings in the container cost. Our own company has always stressed the slogan "The Container is Part of the Product", since all the efforts expended by the manufacturer to create a quality product are in vain if it arrives at destination in a damaged condition. Many shippers now maintain their own package engineering staff, and when such is the case, the container supplier should work very closely with these individuals. Each has complete knowledge of his product; its strong points and its weak ones, the manufacturing limita-

tions that may be involved, cost features, ease of packing, and many other apparently minor details that can greatly affect the cost or the carrying qualities of the finished package.

Compliance With Existing Specifications

This is a joint responsibility of the customer and supplier. The packing of many commodities is covered by detailed specifications in the Consolidated Freight Classification, government specifications, association specifications, etc. The container manufacturer can't be blamed for quoting on boxes which may not comply with such specifications if this requirement is not included in the invitation to bid. However, if told the type of product to be shipped and the specifications governing such shipments, it then becomes his responsibility to furnish containers complying with these specifications.

Correct Manufacture

It of course is the suppliers' duty to comply with the specifications established and to produce containers of acceptable commercial quality upon which the design and specifications were predicated.

Instruction in Proper Usage

This is another highly important part of the container manufacturer's job. Specifications are based on proper packing and closure of the containers, and poor work here may mean that the containers develop only a fraction of the strength that might be produced. Unfortunately, a shipping department is strictly overhead and there is sometimes a tendency to maintain lower supervision and inspection standards in this department than in other departments, with consequent detrimental effects. This service is a never-ending job since personnel changes in a shipping department necessitate further instruction through which a good container salesman can continue to provide service to his customer far beyond that of taking orders and getting deliveries through on time. For example, not long ago we were advised of abnormal shipping damage on an item for which we had furnished crates for years that had carried safely. Investigation revealed that the customer had arbitrarily reduced the number of nails used in the packing process. An addition of only six nails per crate eliminated the damage on subsequent shipments.

Assistance in Carloading

Proper carloading often is as important as the container design in the prevention of damage. A well qualified container salesman not only has knowledge of his product but also of good carloading procedure which will permit him to render valuable service to his customer. For instance, one of the large water heater manufacturers whom we serve has reduced his shipping damage from an excessive amount to less than one unit per thousand by a change in carloading practice along with a minor change in the crate.

Inspection of Shipments on Arrival

Most national container manufacturers are able to check the condition of test shipments on arrival at various parts of the country. This will frequently permit them to suggest improvements in crating or carloading which will reduce damage or possibly lower the cost of the container. Written reports by consignees are fine but are seldom given by competent packing engineers and as a consequence often do not give sufficient information to permit evaluation of the container and subsequent improvement. We recently uncrated, examined and repacked three carloads of automatic washing machines after shipment, and an evaluation of the results allowed us to reduce the cost of the crate by 12 percent.

We are proud to state that we believe the container industry is doing an excellent job in fulfilling its various responsibilities. Damage will never be eliminated entirely since packing is entirely an overhead item and the cost is so important. It would be a simple matter to pack most items so that they could never be damaged if cost were not a primary consideration, but competition between different types of containers as well as between supplies of the same item enforces the design of the cheapest container possible. It then sometimes happens that because of shipping department budgets, the customer insists on a still cheaper package which may eliminate all margin of safety in the shipping container. Thus, there is a joint responsibility to obtain good packages and a limit past which neither must go in reducing specifications. Actually, most shippers do not strive for a perfect shipping record since this would indicate over-packing by a container

more expensive than might be used. Thus, occasional damage indicates that the container is adequate for normal shipping yet not overdesigned to withstand the abnormal shocks that goods in transit sometimes receive.

Testing of Containers

As previously mentioned, arriving at the correct specifications is probably the most important step in reducing shipping damage, and this can be done most efficiently in the laboratories of container manufacturers. Here, qualified package engineers with a background of experience in packing every conceivable product, study the specific problem at hand. They consider the handling received in the shipper's plant, the probable handling in transit, the length of the trip, rehandlings or inspections required, and other facts pertinent to the shipment. After the engineers have decided upon the specifications, samples built to these specifications are actually tested. Unfortunately, package engineering is not an exact science and none of us can say with certainty that a 4½-inch crate slat will carry, but a 4-inch slat would surely fail. Thus, a number of testing devices have been developed over a period of years to reproduce the conditions encountered in actual shipment, and which can be controlled and duplicated so that comparative figures can be obtained and evaluated. Actual trial shipments are of course the finest and surest tests possible, but usually they are impractical from a standpoint of time and cost. By rapid laboratory tests, results can be obtained which are an excellent indication of the crate performance to be expected in final shipments. The more common testing devices and their functions are listed as follows:

Incline Impact Testing Machine

The incline impact testing machine (Fig. 1), often called the Conbur Tester, was originally developed by the Freight Container Bureau. It is primarily intended to simulate the shocks which a container receives in transit during humping or coupling, but it is also an excellent method of producing controlled blows and can be used to duplicate other types of rough handling. The package to be tested is placed on the free running "dolly", which is raised up to a predetermined height on the inclined track

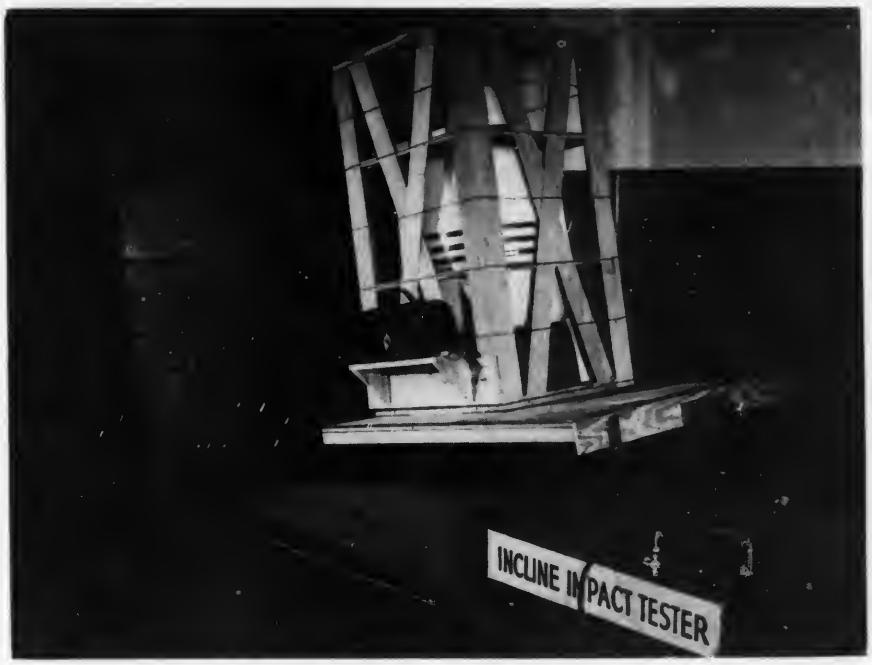

Fig. 1.—Incline-impact (Conbur) tester.

Fig. 2.—Vibration or shaker machine.

Fig. 3.—Revolving drum.

and then released so that it and the package strike the barrier at a calculated speed. The package can be placed flush with the leading edge of the dolly or extended out over it. All faces or edges or even corners can be subjected to such impacts according to the results desired. It is an excellent method of testing and one of those most frequently used in testing shipping containers.

Vibration or Shaker Machine

The vibration or shaker machine (Fig. 2) is intended to reproduce and intensify the vibration encountered by a container in transit. The actual vibration depends on a great many factors; the speed of the train, the condition of the road bed, the condition of the car and its springs, the weight in the car, etc. This vibration can frequently be damaging to both container and contents. It is extremely difficult to correlate time on this machine to distance traveled by a shipment because of so many variables, but intensified vibration is produced which will develop any weakness in either the container or product which might be brought out by vibration in transit.

Revolving Drum

The revolving drum turns (Fig. 3) at a constant rate and subjects the container to controlled rough handling in which the faces, edges and corners are given blows by the scientifically placed hazards within the machine. Since the same blows are duplicated for packages of the same size and shape, it is an excellent method for comparing two types of packages as well as for providing information concerning the general strength of the container. These machines are available in two sizes; seven feet in diameter and fourteen feet in diameter. The smaller drum as shown will accommodate packages up to 20 inches in any one dimension and 250 pounds in weight. The large drum can be used for packages up to 42 inches in length and approximately 600 pounds in weight.

Compression Testing Machine

As the name implies, the compression testing machine (Fig. 4) is used to determine the compression strength of the container. It can be used with the pressure applied flat on a top, side, or end of the box to check the stacking strength, or the pressure may be applied diagonally from one edge to another to determine

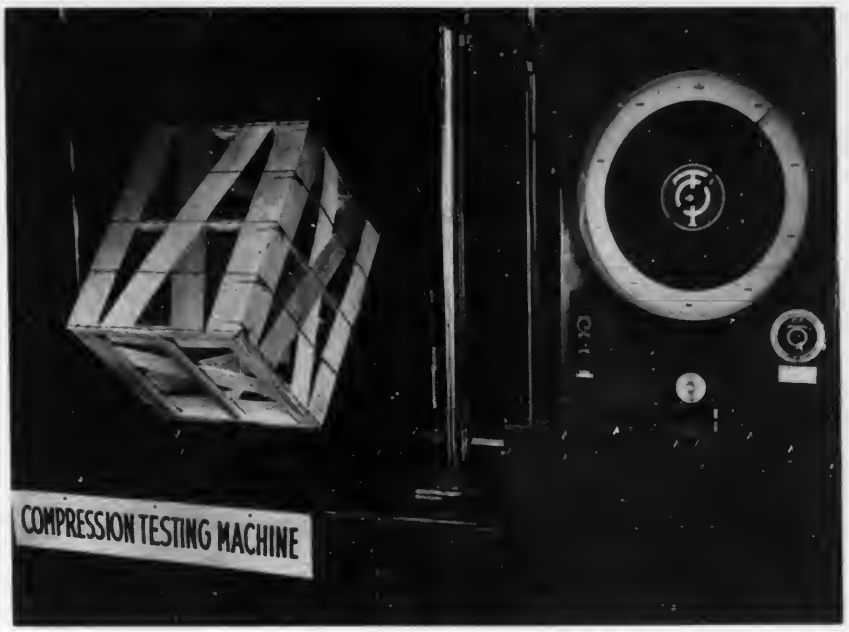

Fig. 4.—Compression testing machine.

Fig. 5.—Package drop tester.

Fig. 6.—Heavy-duty drop tester.

the resistance to distortion of the box sections. It may also be applied from one corner to the diagonally opposite corner. This method stresses all six panels of the container and frequently reveals important information to the crating engineer.

Drop Test

It is always necessary to anticipate the possibility of a container being given accidental falls, and so controlled drops are used in the laboratory to measure the resistance of a container to damage of this nature. These falls can be made on faces, edges, or corners, and are produced by the lightweight package drop tester (Fig. 5) or by the heavy duty drop tester (Fig. 6). Unfortunately, no universal standards have yet been established for these tests and the height from which the subject is dropped depends upon its weight and nature.

Mullen or Cady Tester

The Mullen or Cady Tester (Fig. 7) has long been the accepted standard for measuring the bursting strength of corrugated and solid fibre board. In this test, hydraulic pressure is exerted through a rubber diaphragm against a one square inch area of the test specimen. The pressure required to rupture this specimen is re-

Fig. 7.—Mullen and General Electric (Beach) testing machines.

corded by the gauge in pounds per square inch, which is the industry method of classifying the strength of this material.

General Electric Puncture Tester

The General Electric Puncture Tester, (Fig. 7), also called the Beach Tester, offers a means of measuring the resistance to puncture and the stiffness possessed by a material. A pyramidal puncture point is attached to the end of a pendulum which is released from a constant position and swings through an arc before puncturing the test specimen. Weights can be attached to this pendulum to vary the striking force as may be desired, and the force required for puncture is read from the scale of the machine which translates it into inch-ounces per inch of tear of the specimen.

Other testing machines: There are a number of other specialized instruments for testing containers or component parts thereof such as the "G" meter, the ring crush tester, Elmendorf Tester, etc., but the above mentioned methods are usually adequate to determine the serviceability of a container.

Programs to Reduce Transit Loss

A fine project illustrating cooperation between the shippers, carriers, and the container manufacturers originated about two years ago and the results are now becoming apparent in reduced damage in transit. In early 1948, the Porcelain Enamel Institute sponsored the formation of a National Safe Transit Program under the guidance of the National Safe Transit Committee. This Committe was made up of representatives of major appliance and allied metal product companies, the carriers, and the packaging industry. They decided that the staggering losses which had been sustained in transit necessitated the adoption of some type of pretesting which would indicate crating procedures that would prove to be satisfactory for shipment. After a great deal of study, a system of pre-testing was established which required only the vibration testing machine, the incline impact tester and the package drop tester. Standards were established according to the weight and nature of the product, and laboratories of shippers, independent organizations and container manufacturers were certified for the program. Manufacturers whose packaged products test satisfactorily are entitled to affix the Safe Transit Label to these products, which in itself encourages safe handling. This is still a relatively new program but one which has aroused wide interest in this and in other industries. All indications are that it is greatly reducing the loss in transit, and many manufacturers say that it has actually reduced their costs also since the tests have resulted in improved methods of packing with more efficient use of the material required. The National Safe Transit Committee statement of policy says: "If you will test your packaged products by these test procedures, experience has shown that your loss and damage and your packaging costs will be acceptable minimums. It is up to each shipper to decide whether or not he will use these test procedures. The program is entirely voluntary and implies no connection with tariffs, freight rates, claim procedures or any other existing transit regulations."

The container industry has undertaken various projects to learn more about transit damage and how to prevent it. An extensive study is currently being carried out jointly by the railroads and the Fibre Box Association. Three inspection teams composed of members of each group are inspecting shipments in transit and at destination. When damage is found, a detailed study is made to determine its cause and whether it should be attributed to inadequate packing, carloading, rough handling, or unknown causes. This program was started in September 1949, and no results have been published to date, but the reports to be made at the conclusion of this project will surely be of value to all in producing safe shipments.

A somewhat similar program was carried on for three years by a corporation called the Shipping Container Institute. This was an organization established to discover and correlate the true facts relating to transit damage to merchandise being shipped in fibre boxes, and it was supported by sixteen large manufacturers of corrugated and fibre containers. In cooperation with the box manufacturers, the carriers, the shippers, and the consignees, the Institute obtained comprehensive data on a large number of shipments which could be analyzed for pertinent facts relating to damage. On each shipment it received the following reports: 1. A report from the container supplier relating

specifications and manufacturing details. 2. A report from a testing laboratory giving an analysis of the boxes and materials. 3. A report from the shipper describing the packing, handling, and loading of the merchandise. 4. A report from the consignee or from an inspector describing the condition of the boxes and contents at destination. This program was originated in early 1946 and the Institute was disbanded in May, 1949. The reports and findings are now being made public and contain much information helpful to the carriers and shippers as well as to the container manufacturers.

Another example of industry's efforts to provide better packaging is the engineering course recently sponsored by the Wirebound Box Manufacturers Association wherein a very detailed and complete course in the designing and use of wirebound crates and boxes was offered to all interested personnel in the industry. This was conducted as a correspondence course supplemented by periodic clinics, and was organized to develop competent engineers well qualified to design and service adequate containers. Such programs will result in safer shipping and in more economical shipping since a well engineered package means a balanced package with only an adequate margin of safety.

The Society of Industrial Packaging and Materials Handling Engineers provides another meeting ground of the representatives of the shippers, carriers, and container suppliers. Through their meetings and annual conventions, a great deal of information is disseminated which is sure to result in reduction of losses. The Safe-Packing contest conducted as a part of their annual convention tends to focus the attention of top management on this phase of industry which is too often delegated to a shipping clerk.

Package engineering is a relatively new science, but it is one which is rapidly receiving more attention. Several colleges have recently instituted courses in this subject, and short courses are now conducted annually at the conventions of the SIPMHE. Large shippers can easily justify the maintenance of their own package engineering department but smaller concerns can do equally well by utilizing the services offered by their container supplier.

It seems evident that these various programs and facts are achieving success for although the final damage figures for 1949 are not published at printing date, indications are that the amount charged to this account will be reduced approximately $20,000,000 from 1948 and that a further reduction will occur in 1950. The carriers themselves have of course played a major part in this successful program, but the container manufacturers deserve credit also.

Relation of Problem to FPRS

As a representative of the container industry, it is a pleasure to have the opportunity to present our position on this problem to the members of the Forest Products Research Society for discussion. The entire cost of Packaging and Packing has been estimated to approximate nine billion dollars annually or more than the sales volume of U. S. Steel and General Motors combined. During the various war years, it was estimated that from 20 percent to 35 percent of the total production of lumber went into boxing and crating, whereas in normal years this figure approximates 15 percent. Of the 20,000,000 tons of paper used in the United States per year, approximately 5,000,000 tons are used in the manufacture of corrugated boxes. This all adds up to a tremendous market and also one which utilizes grades of lumber which would otherwise be difficult to sell. Thus our problem is one of particular concern to this entire group and we welcome your interest in it.

Loss and Damage in Transit in Relation to Shipping Containers (What Can be Done by the Manufacturer to Reduce This Loss)

W. B. Keefe

Packaging Engineer, Westinghouse Electric Company, Mansfield, Ohio

Along with the steady rise in volume and value of shipments of finished appliances and allied metal products, there has also been an increase in claims for damage in shipment of these products. To reduce such damage and resultant claims and promote good will between manufacturers and carriers, the National Safe Transit Committee was initiated. The objective of this Committee is to encourage the testing of packaged products by test procedures that will measure their adequacy or resistance to damage during shipment. The program is entirely voluntary.

Introduction

BECAUSE, we at Westinghouse, believe wholeheartedly in objectives and methods of the National Safe Transit Committee, we have given of our time and effort to support the program and become active on this Committee.

The basic objectives of the Safe Transit Committee are the expansion of a practical program for reducing damage to packaged products during handling and while in transit and enlisting the cooperation of all manufacturers of these products for putting such a program in operation.

A statement of policy of this program is simply saying to the shippers: "If you will test your packaged products by these test procedures, experience has shown that your loss and damage and your packaging costs will be acceptable minimums. It is up to each shipper to decide whether or not he will use these test procedures. The program is entirely voluntary and implies no connection with tariffs, freight rates, claim procedures or any other existing transit regulations."

It was believed actual shipping records of both types of products—those that have had good shipping records and those that have had bad shipping records—was the basis upon which any recommendation should be made. The Technical Planning Division of the committee has developed technical procedures and equipment for testing, *before shipment,* the ability of the packaged finish metal product to withstand normal handling from the production line to the consumer.

Outlines of the National Safe Transit Committee Program

After considerable study and actual tests, the Technical Planning Committee devised a test specification for products weighing 100 to 1,000 pounds (Project I) and for products weighing 1 to 100 pounds (Project IA). Both specifications have been approved by the industry and carriers.

The manufacturer's part in this cooperative program consists of a proven pre-testing plan for packaged products that will predetermine their shipability and resistance to normal handling damage. The manufacturer may know in advance whether his product is properly constructed and safely packaged for shipment.

The Safe Transit Committee confines its activities to the testing of packaged products—neither the package nor the product separately. It is not the Committee's intent to interfere with the prerogatives of the individual manufacturer in his design, fabrication or packaging techniques. Preshipment tests, as devised, will predetermine whether packaged product will arrive at its final destination safely. Structural strength built into an article to overcome inadequate packaging is costly and unreliable. Packaging strength sufficient to protect an article with a structural weakness is also costly and undesirable. In both cases, transit damage will likely be excessive.

A change in the package, a change in the product, or a change in both, made on the basis of tests established by this committee are left wholly to the manufacturer's discretion.

The manufacturer may install two pieces of test equipment for heavy units and a third piece for the light units for conducting in-plant tests. The approximate cost of equipment is $2,000.00.

As an alternative, the manufacturer may rely on established laboratories for conducting the specified tests and certifying the results.

The magnitude of the shocks imposed on a packaged unit by ordinary hazards in transportation and handling has been accurately measured by special instruments.

The Safe Transit Pre-shipment Test Procedures are based on the reproduction of these shocks in the testing laboratory and, properly applied, they will show the shipability of the packaged unit. These are strictly performance tests.

The manufacturer must determine for himself causes of any failures, whether it is in his container, his product design, or both.

Testing Procedures

The complete details of the Testing procedures for Project I and IA are as follows:

Project I

This procedure for Project I of the National Safe Transit Program, as developed by the Technical Planning Division of the National Safe Transit Committee, covers testing of packaged products weighing 100 to 1000 pounds as prepared for transportation, and supersedes all previous procedures.

Test cycle shall consist of:

1. Vibration Test
2. Impact Test

Tests shall be conducted in the above order.

Vibration test equipment. L. A. B. Package Tester or other equipment producing equivalent results.

Test procedure. The packaged product shall be placed on the table of the vibration tester; fences may be attached to the test table suitable for the product being tested. Vibration frequency shall be such that the packaged product leaves the table momentarily at some interval during the vibration cycle (equivalent to acceleration of 1g +). The test shall be conducted for a minimum of one hour.

Note: A simple method of determining "1g +" is to advance the cycle of vibration until a thin piece of cardboard can be inserted between one bottom edge of packaged product and the platform of the machine.

Impact (longitudinal shock) Test Equipment. The Conbur Incline Testing Device or other equipment producing equivalent results.

A shock recorder known as RS two-way recorder No. 2W–330, or equivalent.

Test procedure. The container to be tested shall be placed on the dolly with the face or edge which is to receive the impact projecting two inches beyond or flush with the forward end of the dolly.

The shock recorder shall be positioned on the packaged product to record the maximum shock received during the impact test. This instrument should be mounted on a special mounting board. The mounting board should be as long as the side of the container on which it is mounted. The recorder should be placed so that a center line through the length of the recorder is at right angles to the plane of the backstop. (On solid wooden boxes no mounting board is necessary).

When conducting the test the dolly and container shall be drawn up the incline to the predetermined position (the position shall be such as to produce impact into the 1st quarter of the 5th zone of the shock recorder) and released. This test shall be repeated so that each face of the container and the bottom is subjected to the impact. This shall constitute a complete standard impact test. The position of the container on the dolly and the sequence in which the faces or edges are subjected to impacts may be at the option of the manufacturer and will depend on the packaged product under test.

The packaged product shall be considered to have satisfactorily passed this test, if the product is free from damage upon unpacking.

The number of Packaged Products to be tested is left to the judgment of the manufacturer; however, the sample should be sufficiently large to assure valid results.

Note: When it is desired to create a hazard to concentrate the impact at any particular point of the packaged product attach securely a 4-inch by 4-inch wood member across the face of the backstop at the point where it will make the desired contact.

Project I-A

This procedure for Project I-A of the National Safe Transit Program covers testing of packaged products, both single and multiple packed, weighing under 100 pounds as prepared for transportation.

Test cycle shall consist of:

1. Vibration Test
2. Drop Test

Tests shall be conducted in the order indicated.

Vibration test equipment. L. A. B. Package Tester or other equipment producing equivalent results.

Test procedure and performance limits. The packaged product shall be placed on the table of the vibration tester; fences may be attached to the test table suitable for the product being tested. Vibration frequency shall be such that the packaged product leaves the table momentarily at some interval during the vibration cycle (equivalent to acceleration of 1g +). The test shall be run for a minimum of one hour.

Drop Test Equipment. The apparatus shall consist of the following:

(a) Divided table top drop tester such as Acme Drop Tester or other equipment producing equivalent results.

(b) Hoist with suitable sling tripping device. Surface on which package is to be dropped must be a flat firm base (such as steel or concrete).

Test procedure and performance limits procedure. The procedure for identifying faces, edges and corners of containers shall be as follows:

(a) Facing one end of the container, with the manufacturer's joint, if any, on the observer's right:
Designate top of container as one.
The right side as two.
The bottom as three.
The left side as four.
The near end as five.
The far end as six.

(b) Identifying edges by numbers of two faces that form that edge: *Example:*
1–2 identifies the edge formed by the top and right side.
2–5 the edge formed by the right side and the near end.

(c) Identifying the corners by the numbers of the three faces that meet to form that corner. *Example:*
1–2–5 identifies the corner formed by the top, right side, and near end.

The packaged product shall be dropped from the prescribed height (see performance limits) in the following sequence which constitutes a drop test cycle:

(a) A corner drop on the 5–1–2 corner.
(b) An edge drop on the shortest edge radiating from that corner.
(c) An edge drop on the next shortest edge radiating from that corner.
(d) An edge drop on the longest edge radiating from that corner.
(e) Flatwise drop on one of smallest faces.
(f) Flatwise drop on opposite smallest face.
(g) Flatwise drop on one of medium faces.
(i) Flatwise drop on one of largest faces.
(j) Flatwise drop on opposite large face.

Performance limits.

1. Weight of Packaged Product—50 pounds and under. Articles—Single or multiple packaged products such as washing machine tubs, table tops, stove panels, etc.—Drop—24 inches.

1a. Weight of Packaged Product—Over 50 pounds and under approx. 100 pounds.
Articles—as in 1.
Drop—12 inches maximum or 72 inches on Conbur (optional).

2. Weight of Packaged Product—50 pounds and under.
Articles—Completely assembled products (and allied parts) such as roasters, cookers, hot plates, etc.
Drop—18 inches.

2a. Weight of Packaged Product—Over 50 pounds and under approx. 100 pounds.
Articles—as in 2.
Drop—12 inches minimum or 72 inches on Conbur (optional)[1].

3. Weight of Packaged Product—50 pounds and under.
Articles—Hollow ware.
Drop——12 inches minimum.

3a. Weight of Packaged Product—Over 50 pounds and under approx. 100 pounds.

Articles—as above.
Drop—12 inches minimum or 72 inches on Conbur (optional)[1].

The packaged product shall be considered to have satisfactorily passed this test, if upon unpacking, the product is free from damage.

The number of packaged products to be tested is left to the judgment of the manufacturer; however, the sample should be sufficiently large to assure valid results.

The Carrier's Program—Project II

The carriers responsible for handling the finished product in transit, including railroads, express agencies, truck lines and airlines have an important part to play in the program.

In-transit research into the causes of damage, education of employees and handlers and improvement of rolling stock are among the problems being tackled.

Project III and IV

The development of recommended loading procedure and the preparation of instructional placards are being carried on by a carrier-and-industrial sub-committee to help reduce damage for loading practices.

A Loading Manual is being currently worked up which will be distributed to manufacturers.

Labeling Program

One important part in this plan is the Labeling Program made available to companies certifying the use of the plan.

The distinctive red and yellow label serves to point out to handlers that the packaged product has been pre-tested for safe shipment. It also shows that the producer is doing everything to deliver the product in a salable condition.

Some Results of the Program

Continuously, since its organization, the Technical Planning Division has been conducting correlation tests with the various carrier groups and in all cases the established test specifications have been verified by the results of the actual correlation tests.

The Supervisor of Shipping at our Mansfield Plant informs me that we ship more than 1,000 carloads a month for which we purchase from the railroads $300,000 worth of transportation.

The transportation companies have only service to sell. In that service, we are entitled to prompt delivery of the car and the merchandise in good condition.

Several times each year we ask our consignees for a report on the conditions of the cars as received. We have just completed a survey covering shipments throughout the U. S.

1. When was car received?
2. What was the condition of the car blocking and packing cases?
3. How much merchandise was damaged, if any?
4. Did you notify the railroad company and what was their report?

The results of the survey can be summarized very briefly as follows:

1. Total number reports received—90 cities.
2. Total number cars shipped—253 cars.
3. Total number pieces of merchandise—15,600.
4. Number cars blocking was loose or broken —30 cars.
5. Number of packing cases damaged—187. Number products damaged—25.

We consider this a satisfactory performance. Through constant effort and diligence of all interested parties, I am sure that this method of approach can establish a record of real improvement on the shipping records of major appliances and allied metal finished products.

Discussion

Mr. Geo. J. Merten (Evans Products Company): Has your company noticed an appreciated decrease in damage with the use of your label variative technique?

Mr. Keefe: At present, our damage losses are the lowest they have ever been. These results are attributed to several factors—one of which is the variative Fragile Label; another, the pre-performance tests according to the National Safe Transit Program.

We have no direct method of measuring this decrease in damage as to how much can be credited to the informative labels but we know that our over-all program has helped to decrease and maintain our low damage figure.

[1] If the use of Conbur Incline Testing Device is elected, the sequence of the test will be as described under Drop Test.

TECHNICAL SESSION III

Monday, June 26, 1950, 1:30 P. M.

General Subject: Pulp and Pulpwood Supply Developments

Chairman: Colonel W. B. Greeley, Vice-President, West Coast Lumbermen's Association, Seattle, Washington

Recorder: Paul N. Vance, Wood Supply Manager Fir-Tex Insulating Board Company, St. Helens, Oregon

P. N. Vance, Col. W. B. Greeley.

Economic Aspects of Papermaking Fibrous Raw Materials

Louis T. Stevenson

Economist, American Paper and Pulp Association

Northeast Europe, the United States, and Canada are the main areas of the world bearing pulpable species. The lead in pulping processes in the United States has shifted from sulphite to sulphate pulp. In 1960 a total of 30 million tons of paper and board will be needed for United States consumption.

Introduction

THE paper industry is an old industry, as industries go. It far antedates such industries as the railroad industry, the motor car industry, and the electrical industry, to say nothing of those vigorous youngsters, the airplane and radio industries.

Ever since its founding in China in the first century A. D. the paper industry has been searching for new, better, and cheaper raw materials. In the first seventeen hundred years it had found nothing more satisfactory to widen its raw material base than linen and cotton rags. About the year 1800 Scheele's experiments resulted in the application of chlorine to the bleaching of colored rags for the production of white paper, thus enlarging the raw material base for that most important product of the industry.

Research had been undertaken before that time by a number of individuals into the possibility of using annual growth fibers for papermaking. Jacob Christian Schaeffer, between the years 1765 and 1772, made paper from eighty different vegetable fibers.

Paper, being made from cellulose fibers, can use for its raw material any leafy green plant. Papermakers have therefore practically an inexhaustible supply of raw material. The main problem is the economic choice of which one to use. To be sure, each of the raw material sources is endowed with different physical and chemical characteristics. Each has its problems of assembling and harvesting. But each is a potential competitor of all others, and is therefore an economic factor that gets balanced, either consciously or unconsciously, by the paper manufacturer in his choice of the fibers from which to make his products.

Principal Fibrous Materials

The principal fibrous raw materials used in papermaking today are:

> Wood pulp of various kinds and grades, waste paper, straw, rags, flax, cotton (staple and linters), manila stock, and various other fibers such as used jute rope.

The foregoing list represents the major raw materials used in the United States. For England and the European continent the list should include esparto grass from Spain and North Africa.

The relative importance of these raw materials to the United States paper industry will be recognized by the fact that in 1948 wood pulp was 61.4 percent and waste paper 32.4 percent, or a total of 93.8 percent of all the fibrous material consumed. The following tabulation gives the detailed percentage breakdown of fibrous materials for the years 1944 and 1948:

Material	1944 Percent	1948 Percent
Rags	2.28	1.78
Paper Stock	36.59	32.40
Manila Rope	.05	Included in Other
Straw	2.97	2.23
Other	2.09	2.19
Total	43.98	38.60
Wood Pulp	56.02	61.40
Grand Total	100.00	100.00

The 1944 data are strongly influenced by the wartime conditions of wood pulp shortages in the United States, while the 1948 data show a more normal competitive structure.

Including wood pulp, which will be discussed at length somewhat later, all these materials are waste or "scavenger" materials. They are by-products discarded after the primary util-

ity has been absorbed in the production of some other good or service. Each one presents a collection problem of no mean importance. The collection of waste paper, for example, is a well organized business, but less than 30 percent of the total paper and board consumed (including imports of newsprint) normally reaches the paper mills again as a raw material in the shape of waste paper. The balance is destroyed either in or after its primary use.

Wood Pulp the Major Papermaking Material

The foregoing tabulation shows that in 1948, if the wood pulp content of waste paper is counted, 91 percent of papermaking fibrous raw materials originated in the woods. More than 61 percent was virgin wood pulp and about 30 percent was reused in the form of waste paper.

World's Wood Distribution

The accompanying map (Fig. 1) of the world on Mercator's projection will give a broad picture of the distribution of the world's forest resources. One should recognize, when looking at this map, that Mercator's projection of necessity distorts, by stretching out, the extreme northern and southern hemispheres. In this map it tends to overemphasize the acreage of conifers in the northern hemisphere. Nevertheless the map shows the dominant position of the northern hemisphere with respect to the conifers. These areas are shown in black. The almost treeless areas appear as white areas. It is easy to pick out the white areas of the plains states in the United States and Canada, the Argentine pampas, the Sahara, Gobi, and Australian deserts, the steppes of Russia, and the South African veldt.

Dominance of Coniferous Wood

"The pulping industry has been utilizing soft coniferous woods primarily for several reasons, among which, for example, may be cited:

(a) The longer fibers of the conifers have been considered indispensable for strength properties,

(b) The generally more porous structure has provided greater facility in the penetration of chemicals for chemical pulping,

(c) The combination of longer fibers and softer structure have made the conifers better adapted to mechanical pulping with superior results."[1]

[1] W. E. Byron Baker, Manager Paper Research, New York and Pennsylvania Company.

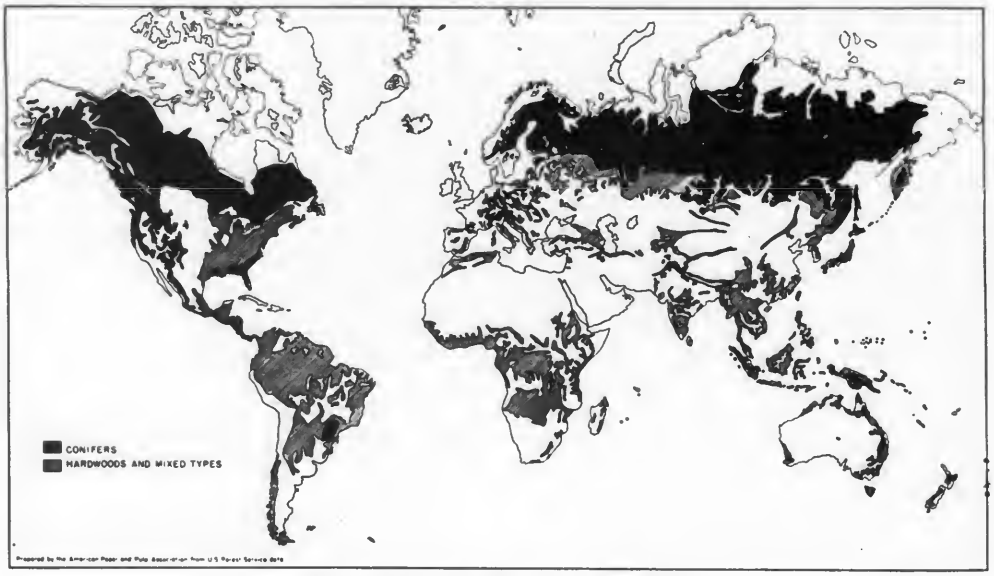

Fig. 1.—Important timber areas of the world.

Due to these features coniferous wood is the dominant pulpwood for use in the following pulping processes: (1) sulphite, (2) groundwood, (3) sulphate, (4) soda.

The semichemical pulping process, which has been developed comparatively recently, is being used successfully in the pulping of both hardwood and softwood. It seems to have a great future ahead for hardwood pulping.

Volume and Availability of Pulpwood

The dominant position of the northern hemisphere with respect to coniferous wood and the adaptability of that wood to the major pulping processes results in the fact that almost the entire world production of wood pulp is in the northern hemisphere. There is some wood pulp production in South America, Australia, New Zealand, and South Africa from native woods. But compared with the northern hemisphere production it is not significant.

Accessibility of wood supply is an important economic factor that has its effect upon northern Canadian, Russian, and Siberian wood supplies. Mainly because the rivers in these regions run north into the Arctic ocean and are frozen for most of the year and because of the human and operational difficulties of operating in these areas, there is little use made of these forests for pulping.

That leaves northeast Europe, the United States, and Canada,—west coast and St. Lawrence basin,—as the main accessible forest areas bearing coniferous wood. These are the paper-making areas of the world, and accessibility of pulpable species is the principal reason.

Regional United States Supplies of Wood

The latest available comprehensive survey of the United States forests gives the status at the beginning of 1945 and the following discussion and tables are based on that Survey.[2] Drain, wood pulp, and pulpwood data are for the year 1944 unless otherwise noted.[2]

In the accompanying maps (Figs. 2 and 3) timber stand, growth, and drain are shown in millions of cubic feet by regions. The shaded areas represent the timber stand, plotted on the same scale for comparison. Fig. 2 shows these

[2] Pulpwood receipts data, American Paper and Pulp Association Pulpwood Survey and Wood Pulp Production, U. S. Pulp Producers Association; Forest data, Forest Service Report I, from a Reappraisal of the Forest Situation issued in 1946.

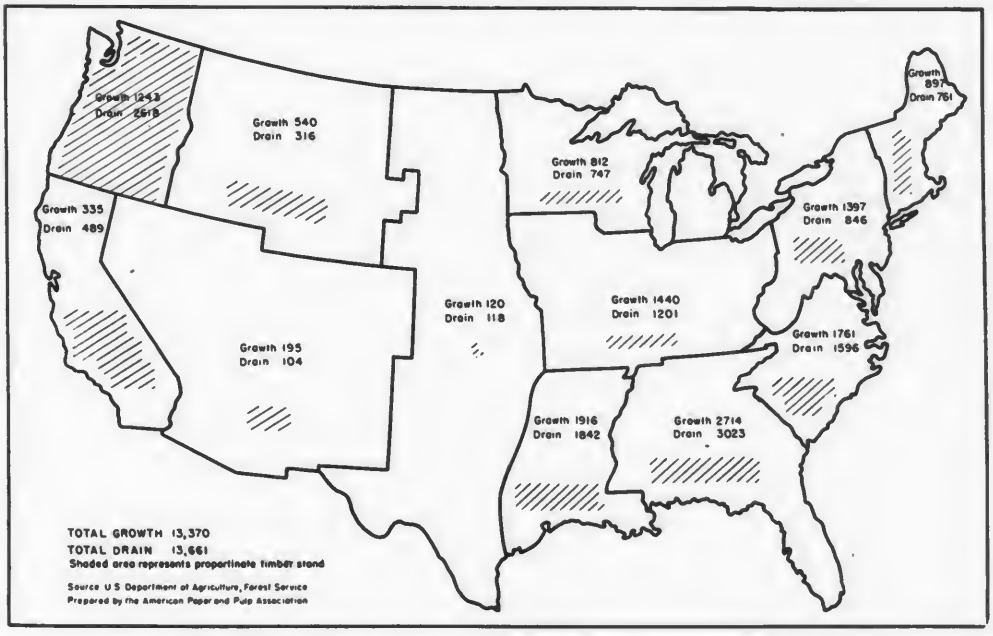

Fig. 2.—Total timber stand, growth, and drain in million cubic feet by regions, 1944.

TABLE 1.—TIMBER STAND, GROWTH, AND DRAIN IN MILLIONS OF CUBIC FEET BY REGIONS

Region	All Timber			Softwood		
	Stand	Growth	Drain	Stand	Growth	Drain
New England	24, 626	897	761	11, 318	419	375
Middle Atlantic	27, 359	1, 397	846	5, 376	273	180
Lake	23, 200	812	747	7, 000	178	323
Central	20, 992	1, 440	1, 201	1, 479	95	49
Plains	3, 723	120	118	269	11	7
South Atlantic	35, 965	1, 761	1, 596	17, 031	1, 007	1, 063
Southeast	54, 220	2, 714	3, 023	23, 841	1, 480	1, 789
West Gulf	40, 689	1, 916	1, 842	17, 460	1, 033	851
Oregon and Washington	145, 879	1, 243	2, 618	144, 122	1, 211	2, 613
California	44, 600	335	489	44, 600	335	489
No. Rocky Mt.	33, 350	540	316	32, 926	537	310
So. Rocky Mt.	15, 442	195	104	14, 575	177	102
All Regions, Total	470, 045	13, 370	13, 661	319, 997	6, 756	8, 151

data for the total timber stand; Fig. 3 for softwood. Table 1 is the basis for these maps.

Wartime Data

It should be recognized at once that this picture represents almost peak wartime conditions. The nation was putting forth its maximum wartime effort with the feeling that all possible sacrifice must be made to support the boys in the armed services.

Broad Facts

Taken as a whole it should be recalled that the forests products compete with one another for raw material. The product of the forest, a tree, may be used by anyone of several competing industries. The major uses are indicated in table 2 for the year 1944.

Each one of these consumers of wood has its own particular requirements to which the wood supply must be adjusted. That these requirements may be changed from time to time by technological developments is well illustrated in the case of pulpwood for the paper industry where the southern pines 45 years ago were considered unpulpable, and are now our largest source of pulpwood.

The constantly shifting economic forces that play upon these industries are reflected in their

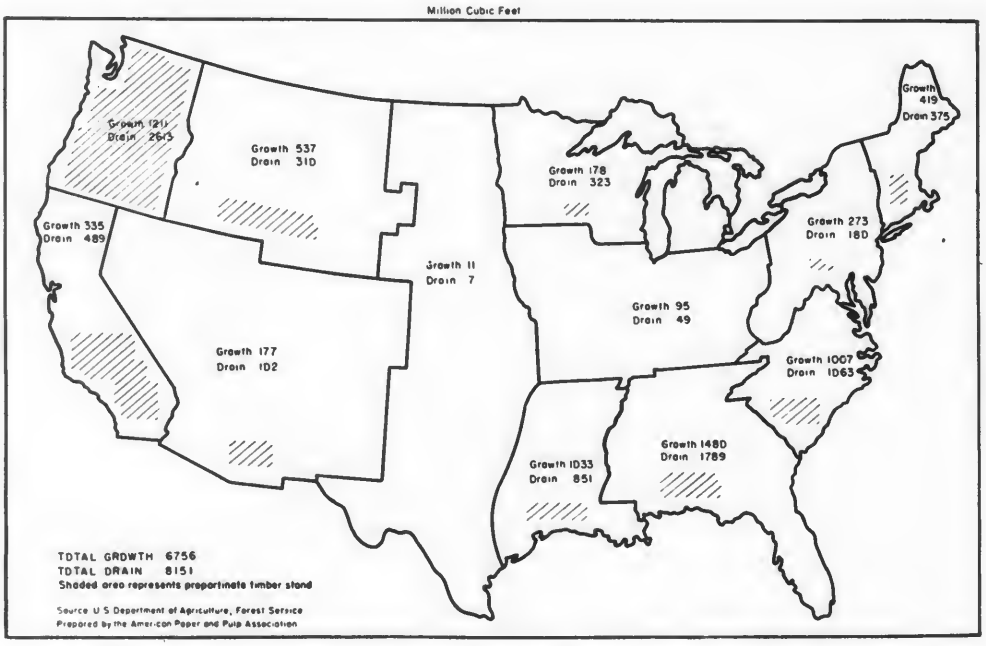

Fig. 3.—Total softwood timber stand, growth, and drain in million cubic feet by regions, 1944.

TABLE 2.—DRAIN ON UNITED STATES FORESTS 1944

Use	Millions Cu. Ft.	Percent of Total
Lumber	6,711	49.1
Fuelwood	2,203	16.1
Pulpwood	1,306	9.6
Hewed Ties	363	2.7
Fence Posts	220	1.6
Veneer Logs	392	2.9
Mine Timbers	225	1.6
Cooperage	174	1.3
Shingles	72	.5
Other	516	3.8
Total for Manufactured	12,182	89.2
Losses by fire	460	3.4
Losses by insects, etc.	1,019	7.4
Total Drain	13,661	100.0

demands for wood. These shifting demands in turn play upon the available supply of wood, the components of which have varying growth cycles, differing conditions of harvesting, of size, location, terrain, growth and species in the different regions.

Pulp Mill Requirements

The pulp and paper industry has been built to its present size largely upon the basis of using wood that was discarded as unmanufacturable by sawmills and other users. The pulp mill was started to consume such by-products of the sawmill by such outstanding operations as those of the Brown Company in New England and the Weyerhaeuser Timber Company on the West Coast. Consequently pulpwood has been a "scavenger" or by-product operation for many concerns. In some cases wood from tree farm thinnings as small as 2 inches in diameter is now being used by pulp mills.

Pulpwood Prices

In addition to cutting pulpwood from company-owned land, a great deal of pulpwood is bought by pulp mills from small landowners. No accurate measure of the percentage this bears to the whole is available, but current estimates run from 70 percent to 75 percent for the areas east of the Rocky Mountains. The prices paid for this small landowners' wood must compete with those paid by users other than pulp mills, and so indicate the competitive position of pulpwood in the market for forest products. Table 3 shows the average value per cord over a period of years for purchased pulpwood:

TABLE 3.—PULPWOOD AVERAGE VALUES[1] PER CORD—1947

(f.o.b. Plant)

By Kind:	Value
Total Pulpwood	$17.83
Spruce and True Fir	25.77
Hemlock	18.47
Jack Pine	19.49
Southern Pine	14.44
Poplar (Aspen and Popple)	18.75
Northern Mixed Hardwoods	20.49
Southern Mixed Hardwoods	14.68
Other, including Slabs and Mill Waste	12.02

By Kind and Condition:	Total	Rough	Rossed and Peeled
Total Pulpwood	$17.83	$17.12	$22.74
Softwood—Total	18.00	17.33	25.03
Spruce and True Fir	25.77	24.58	29.99
Douglas Fir	15.21	15.21	n. g.
Hemlock	18.47	18.28	21.56
Jack Pine	19.49	19.39	20.75
Southern Pine	14.44	14.42	15.10
Other, including Slabs and Mill Waste	12.49	12.41	13.44
Hardwood—Total	16.75	15.00	19.43
Northern Mixed Hardwoods	20.49	19.68	21.93
Poplar (Aspen and Popple)	18.75	15.86	20.66
Southern Mixed Hardwoods	14.68	14.49	15.34
Other, including Slabs and Mill Wastes	13.81	5.00	14.29

By Divisions and States:	Value	Value
Total United States	------	$17.83
New England	------	23.23
Maine	$22.70	------
New Hampshire	24.82	------
Vermont, Massachusetts and Rhode Island	27.93	------
Middle Atlantic	------	26.38
New York	28.06	------
New Jersey	13.37	------
Pennsylvania	25.18	------
East North Central	------	22.86
Ohio and Illinois	16.55	------
Michigan	23.35	------
Wisconsin	23.26	------
West North Central	------	18.30
Minnesota	18.30	------
South Atlantic	------	14.85
Virginia	12.28	------
North Carolina	14.35	------
Florida	16.23	------
Maryland, South Carolina and Georgia	15.41	------
East South Central	------	13.07
Tennessee and Alabama	12.75	------
Mississippi	13.47	------
West South Central	------	14.12
Arkansas and Texas	14.02	------
Louisiana	14.17	------
Pacific	------	17.05
California	16.16	------
Oregon	19.59	------
Washington	16.50	------

By Regions:	Value
Total United States	$17.83
Northeast	24.55
Appalachian	16.02
Lake States	21.94
South	14.40
Pacific Coast	17.05

By Years:	Total Pulpwood
1947	$17.83
1939	7.82
1938	8.10
1937	7.97
1936	7.71
1935	7.64
1934	7.73
1933	7.37
1931	10.94
1929	13.09
1919	15.95
1909	8.62
1899	4.95

[1]Source: U. S. Bureau of the Census—Census of Manufacturers 1947.

It will be seen that spruce and true fir pulpwood has brought consistently higher prices and that southern pine has brought consistently low prices. The average value has fluctuated widely over a period of 48 years.

Regional Production of Wood Pulp

The regional production of wood pulp shows the extent to which the wood pulp industry has grown in the regions where pulpwood has been comparatively cheap and plentiful.

A 1944 comparison of wood pulp production by regions with total timber supply for the same regions is shown in table 4.

TABLE 4.—COMPARISON OF WOOD PULP PRODUCTION BY REGIONS WITH TOTAL TIMBER SUPPLY

Region	Total Timber Supply	Wood Pulp Production
	Million Cubic Feet	Tons
New England	24, 626	1, 277, 826
Middle Atlantic	27, 359	811, 379
Lake	23, 200	1, 403, 241
Central	20, 992	72, 396
Plains	3, 723	----------
South Atlantic	35, 965	1, 574, 424
Southeast	54, 220	1, 954, 207
West Gulf	40, 689	1, 346, 254
Oregon and Washington	145, 879	1, 668, 716
California	44, 600	Included above
No. Rocky Mountain	33, 350	----------
So. Rocky Mountain	15, 442	----------
Total	470, 045	10, 108, 443

It will be observed that there was no production of wood pulp in three regions,—plains, and north and south Rocky Mountains. The plains states have very little wood and the other two are remote from markets, with high freight rates and no water-rail competition. A contributing factor is that National Parks and Forests cover a large portion of the area, while logging conditions in these areas have not been too easy.

Grow Trends in Wood Pulp Grades

The kinds of wood pulp that are made depend upon the species of wood that are available and the state of technical developments in the industry. The progress in pulping southern wood has been rapid in the last fifteen years. Between 1934 and 1948 the production of all major grades of wood pulp grew considerably. Production of sulphite doubled, groundwood grew by 2½ times, while soda pulp production increased by less than 50 percent. The major growth, however, was in sulphate and the semichemical grades. Sulphate production grew to about 5 times and semichemical over 6 times the 1934 production.

The following tabulation will give an idea of the relative importance of the major pulp processes:

Process	Percentage of Total Production 1934	1948
Sulphite	33%	22%
Sulphate	28	47
Groundwood	29	23
Soda	8	4
Semichemical and other	2	4
Total	100	100

The lead has shifted from sulphite to sulphate pulp, due largely to the development of the southern pine regions through technological developments in the sulphate pulping process.

State Ranking

Shifts in the state rankings with respect to the production of wood pulp do not occur rapidly. In the three years from 1944 to 1947 the state of Washington retained first place, and Maine and Louisiana followed, in that order.

Future Requirements

Projections of paper and board production into the future indicate that by 1960 a total of 30 million tons of paper and board will be needed for United States consumption. Of these 30 million tons five million tons of newsprint will probably be imported, which leaves 25,000,000 tons for domestic paper and board production. On the basis of 1948 data this will require 26,800,000 tons of raw materials, of which 16,400,000 tons will be wood pulp. This, on the same 1948 basis, would be divided among the grades as follows:

Process	Tons
Sulphite	3,608,000
Sulphate	7,708,000
Groundwood	3,772,000
Soda	656,000
Semichemical	656,000
Total	16,400,000
Allowing for	
Wood Pulp Imports	2,000,000
Leaves (domestic production)	14,400,000

To produce this volume of wood pulp will require approximately 23,000,000 cords of pulpwood of which about 21,500,000 cords

will probably be the portion of domestic wood required. These estimates are based upon the assumption of a distribution of wood among domestic species and imports similar to that of 1949. That this is well within the volume of domestic pulpwood that can be produced without strain would appear from the fact that in 1948 our pulpwood receipts at United States mills were over 22 million cords. A five percent increase in 12 years seems easy of accomplishment.

Conservation Movement

The movement to conserve the forest resources of our country fits in ideally with the interests of the pulp and paper maker, provided timber is grown and harvested on a sustained yield basis. The pulp and paper makers have a tremendously high capital investment and "destructive cutting" operations are also destructive of their sources of raw material. Destructive cutting pushes back the circle of pulpwood procurement until transportation charges eventually become so burdensome that the mills' costs become prohibitive.

With an average investment in 1948 of $23,000 per worker and $214 per ton of annual production, or $66,340 per ton of daily production, the pulp and paper industry is vitally interested in maintaining its investment through assuring a continuous supply of wood at a reasonable cost to the mills. That is the reason why the pulp and paper industry is in the forefront of the commercial practice of good forestry on its own land and is teaching a sound forestry practice to the small landowners that supply pulpwood to it.

Integrated Forestry Operations

It has been found practical in some regions for pulp mills that own forest land to plant seedlings, grow a forest, and in the process to use thinnings for pulpwood and eventually harvest the large trees for sawtimber. These practices are mutually beneficial to both the lumber and pulping industries. It has been asserted that the pulp mill in the South has made possible the continuous operation of sawmills by providing a market for the thinnings from forest land and thereby has helped the timber grower to carry his sawlogs to maturity.

Summary and Conclusions

Paper can be made from any leafy green plant, for the basic fiber is cellulose, which is found in all such vegetation.

The particular fiber used in a given instance is the result of the play of complex economic forces and involves the interplay of the supply of various fibers, the technical processes available for extracting the fibers, and the end-use requirements for the paper to be made.

Coniferous wood has been found to yield the best and most economical cellulose fibers for the mass production of paper. Raw cotton, cotton and linen rags, straw, flax, and jute have been found to have useful fibers for special papers, but 91 percent of the fiber used in papermaking comes from wood.

The northern hemisphere is in a dominant position with respect to the world supply of coniferous wood, the main accessible forest areas being those of northeastern Europe, Canada, and the United States.

Growth and drain of all timber in the United States is respectively about 3 percent of supply. About 10 percent of the drain is in pulpwood, 10 percent lost through fire and disease, and the remaining 80 percent in other wood-using competing industries.

Frequently a pulp mill was started to consume wood considered unmanufacturable by sawmills and other wood-using industries.

The wood pulp industry has developed in regions where pulpwood has been comparatively cheap and plentiful. The kinds of wood pulp made depend largely on the available species of wood. The production of sulphate pulp has increased 5 times since 1934 and has, due to the development of the southern pine region, become the major grade of wood pulp, accounting for 47 percent of the total.

A projection of future requirements indicates that the United States can easily meet its expected 1960 pulpwood requirements without increasing its imports of pulpwood. The movement on the part of the industry to conserve the forest resources of this country is tied-in with the high capital investment of pulp and paper mills, among which there is a growing tendency toward integrated forestry operations.

Discussion

Col. W. B. Greeley (West Coast Lumbermen's Association): Since the saturation point in consumption of paper has not yet been reached, can we utilize unused species such as red alder in the Northwest and poplar and aspen in the Lake States?

Mr. Stevenson: The Forest Products Laboratory is working on alder as well as poplar. During the past 10–15 years, there has been an increase of 5 to 25 per cent in the consumption of poplar. A large variety of species are used throughout the country to make pulp and paper.

Mr. R. C. Fraunberger (Philco Corporation): You mention that average value of pulpwood has fluctuated widely over a period of 48 years. Please elaborate on the secular trend versus the cyclical movements. Do you have figures on stumpage cost, and if so, what per cent does stumpage represent of the value of pulpwood?

Mr. Stevenson: Pulpwood prices in 1947 were double those of 40 years ago. I cannot elaborate on stumpage costs.

Prof. Fritz (University of California): Do your figures include pulpwood usage for hardboard?

Mr. Stevenson: Yes.

From the Floor: Can salt water be used in pulping? We need more water experiments.

Mr. Stevenson: Water is an important subject in Southeastern United States. There is a tremendous drain on the water supply with a resulting drop in the water table. There is a limit to water resources. The Forest Service is conducting studies in management of water supply resources and their water holding capacities. The Antioch Mill is located on tide water of the San Joaquin River in California. It uses up to one third concentrate of ocean water. Salt load is up to 20 per cent in cooking liquor sometimes as a result of salt adhering to logs. Corrosion is a problem, of course.

Mr. R. N. Hammond (Weyerhaeuser Timber Company): Statements from visiting pulp and paper technical men from Finland have indicated the use of sea water throughout a sulfite mill operation. I believe some reference to this operation may be found in the literature.

Mr. J. Alfred Hall (Pacific Northwest Forest Experiment Station): In 1936 U. S. Senate wanted a prediction on pulpwood usage for 1950. The U. S. Forest Service prediction has proven to be correct, so that your 1960 predictions are probably correct, also. There is a great demand for paper in the U. S. It is 358 pounds per person per year compared to 8 pounds per person in Mexico, for example.

FOREST PRODUCTS RESEARCH SOCIETY

Utilization of Low-Grade Hardwoods and Softwoods in the Pacific Northwest

Geo. L. Drake

Vice-President in Charge of Research and Forestry, Simpson Logging Company, Shelton, Washington

Due to the large stands of high quality virgin timber available in the Northwest most of the interest in the low value timbers has developed in the past fifteen years.

In recent years the developments in logging, transportation and manufacturing methods coupled with the enactment of state forest laws have changed the thinking of men responsible for forest planning and have encouraged closer utilization.

In the manufacturing plants, more attention to the yield efficiencies and by-products have also increased utilization.

Research made possible by legislative action in Oregon and Washington will bring closer utilization of both major and minor species.

The better utilization now and expected in the future allows a much sounder forest management policy than has heretofore been possible.

Introduction

FROM the time of the initial settlements in the Pacific Northwest, the economy and prosperity of the region has been directly dependent upon its forest industries; and today, even with the development of other industries, the immediate future depends on the intensive use of its forests. There still remain large stands of virgin timber; and up to the last decade virgin timber of high quality was readily available to the mills of the Pacific Northwest. Consequently, interest in low-value timber has developed only in the last fifteen years.

To properly understand our utilization problems, especially in the virgin stands, one must realize that forest conditions in these stands are vastly different from those in timber stands in other regions of the United States, with the exception of the redwoods. The bulk of the remaining mature timber in the Northwest lies on steep mountains, where the logging costs are high. The steepness of the ground plus the large size of the timber, coupled with its age, leads to heavy breakage, with more debris on the ground after logging than in other regions. The size of the timber varies greatly and machinery heavy enough to handle the larger trees may be very inefficient in logging the smaller trees and material under saw-timber size. Much of the country is so steep and rugged that selective logging is not practical. Clear cutting necessitates the cutting of all classes of timber at one time, which complicates the problem of utilization.

Up to the advent of the bulldozer (which is the unsung hero of present day transportation and logging methods), it was difficult and costly to get the equipment close to the timber; and where long yarding was the practice, only the larger timber and better species paid their way. Today truck and "cat" roads can be built at reasonable cost with bulldozers, even in this steep country, and equipment can be moved closer to the logs. The shorter yarding distance results in more efficient handling of smaller timber.

Concurrent with the development of logging and transportation favorable for closer utilization have been the developments of manufacturing processes. The balance between profitable and unprofitable salvage of timber has always depended on logging costs and what the mill could pay. Hence it was important that the mill be efficient as well as the logging.

The coming of the pulp mills has created a market for hemlock and the true firs. The pulp mills have been able to use smaller logs than the sawmills, especially since the development of the hydraulic barker.

The rapid expansion of plywood plants has created a demand for peeler material. Logs which formerly would not pay their way due to heavy defect are now in demand if peeler blocks can be cut from them. This demand for peeler material has distinctly changed the picture in areas, like the Southern Cascades, where the timber is highly defective. As the supply of high grade fir peeler logs became more scarce, it was found that by patching the ply-

wood, defects could be covered up, and poorer logs were used. Species are now used for peeling which were formerly considered unsuitable.

With this background of the development of better utilization in the Pacific Northwest, it is of interest to study in more detail the trends towards better utilization in various branches of the industry, as well as the few instances where the practices are unfavorable.

Logging Methods

As previously mentioned, developments in better transportation and logging equipment, coupled with more favorable markets, have encouraged close utilization. But most noticeable is the change that has taken place in the thinking of the men responsible for the planning of the woods operations. Areas of small timber, formerly given little consideration, are now being protected from logging damage and from fire. Small trees, especially hemlock, which were formerly knocked down in logging and never utilized, are now being taken out either by prelogging or relogging. Here the development of a market for pulping timber has helped. Thinnings, so important to relieve stagnation and accelerate growth, are being made a matter of study in many parts of the region; and where they can at least pay their way, such thinnings are made under the direction of foresters. The enactment of practical state forest practice laws has been an important factor in getting some to think along these lines.

Improved market conditions and demand from pulp mills are resulting not only in the utilization of small trees but also in the more complete salvage of defective and broken timber. In our own operations, our net railroad car scale has dropped approximately 15 percent in the past five years due to better utilization of small logs, slabs and defective timber. Our recent studies of material left in the woods after logging show a striking decrease.

Changes in scaling practice have also helped to make the small log pay its way, by reckoning the content in cubic feet instead of board feet.

Sawmill Practices

In the larger mills better utilization has been obtained by closer supervision to the end of getting the most out of the log. Species that formerly were not cut in these mills are now being cut generally because of the growing scarcity of Douglas fir and the development of markets. The installation of Swedish type gang saws for cutting logs under 30 inches in diameter has been a factor in better utilization.

Due to the postwar demand for lumber, many small mills, often the portable type, have sprung up in the Northwest. Lumber is cut from small timber, and there is a heavy output of ties. Many of these mills are powered with internal combustion engines and as a result they accumulate large quantities of slabs and sawdust. Until markets can be found for these by-products, the degree of utilization in these small mills will remain far below the standard of the larger, more permanent mills. In addition to their being more wasteful, these mills are having a bearing on the future economy of the region, especially the tie mills, in that they are cutting in second-growth stands coming into their maximum growth, which will be needed later to fill the gap between the virgin timber and second growth.

The use of hydraulic barkers, originally developed for pulp mills, has been extended to at least one large sawmill; and by removing the bark before sawing the logs, all the slabs and edgings are made readily available for chipping. The Douglas fir bark, which comprises approximately 12 percent of the volume of old growth timber, is being processed at this plant into useful products.

Remanufacturing Processes

While progress is being made in reducing waste at the headrig, many mills have made great strides in better utilization through the refinement of products after the initial saving. Uses have been found for slabs, edgings and short lengths which formerly went into the burner; and one plant that now specializes in this field, through a central plant operates twelve salvage cut-up plants in existing sawmills. This type of utilization is one of the most promising fields, one that will provide maximum employment.

In view of the fact that there are large quantities of material now going into fuel or being wasted in the smaller mills, a study of resources is being made by the Washington State Forest Products Institute. This study is making

available data on the quantity, quality and location of this type of material, with the hope that the information will encourage investment in plants to utilize this valuable resource. A study has already been made by the Division of Forestry of Washington State, of the amount of slabs resulting from the operations of the small mills. In some localities this material creates a serious fire hazard.

Plywood

The scarcity of high grade peeler logs and the increased capacity of the industry through new mills has forced the industry to use logs of smaller size and poorer quality. The patching of both face and core veneer sheets is common practice, and specifications have been altered to permit this type of repair in many grades of plywood. Face overlays are being used to cover up surface blemishes. Edge-gluing of small pieces is also common practice. In some plants, trimmings formerly used for fuel are now put to a higher use such as fiberboard.

While the original plywood mills were designed for peeling only Douglas fir, many of the plants are today using other species; and the special problems, such as drying, have been overcome.

The utilization of the cores resulting from the peeling of the logs has shown great improvement. In our own plants the cores are either sawn into ties or cut into core stock in a small lathe.

Bulk Fiber

While great savings have been made through better logging practices and refinements in manufacturing, the most promising developments in utilization have been made in plants that use bulk fiber, such as pulp mills and insulating or hardboard plants.

Studies made of the material left behind in logging, in the form of small unmerchantable trees and broken or defective logs, indicate that this material will best pay its way as bulk fiber. The most successful prelogging and relogging operations are sending this type of material to pulp mills. Thinnings are finding their best market in pulpwood. Leftovers from the sawmills are being successfully chipped and converted into pulp or fiberboard. Our fiberboard plant at Shelton, producing approximately 300,000 feet of insulation board per day, draws its raw material from the leftovers of our sawmills and plywood plants.

Operations that are integrated are taking the lead in close utilization and, what is equally important, in extracting increased employment from the raw material. In our own integration of logging camps, railroad, sawmills, plywood plants, door factory and fiberboard plant, we are employing approximately twenty persons for each million feet of logs produced annually.

Box Material

Ponderosa pine for years has been a dominant species in the box industry, due to the properties of the wood and the favorable location of the pine mills to the fruit-growing regions. With the decreasing pine supply and the increasing demand for boxes, pine is being supplanted by its intermingled neighbors, western larch, white fir, Douglas fir and lodgepole pine. In the past these species were considered unsuitable for box material, due to certain natural characteristics of the wood, but treatment is overcoming these objections. Also, edge-gluing is making possible the use of material formerly considered too small.

Minor Species

The improvements in utilization so far cited cover the use of the major species of the region, but what of the minor species such as lodgepole pine and the hardwoods, red alder, maple and Oregon oak? Due to the growing scarcity of cedar poles plus the active market for transmission poles, lodgepole pine, when treated with preservatives, is coming into its own. For many years there has been a demand for the better grades of red alder and maple for the furniture trade, but practically no demand for the lower-than-shop grades which comprise some 50 percent of the log. Studies being made indicate that this lower grade material is suitable for pulp.

Wood Preserving

Forward strides to better utilization of low-value timber have been made through the working out of processes for treating these woods with preservatives. In the Inland Empire where western larch has been a problem child, the future looks brighter since the American Wood

Preservers Association has prepared specifications for treating western larch ties, lumber and poles. They are also studying the treating of this species for piling.

Research

One of the most encouraging developments in securing greater utilization in the woods and mills is the increasing interest in research. Today many of the progressive companies have well equipped and fully staffed laboratories working on problems of their own operations. Much of the progress I have reported came out of the work of these laboratories and those of the public agencies and trade associations.

The people of Oregon and Washington are recognizing the part research must play in the future of their region. In Oregon a severance tax of 5 cents per thousand feet of all timber cut, makes up a fund of which 60 percent goes to forest products research and 40 percent towards forest management research and planting. This research program is administered by an advisory committee on which industry sits; and the laboratory work is carried on at the Forest Products Laboratory of the Oregon State College with a staff of eight full-time specialists. Through this program, three sections are now functioning: industrial service, chemical utilization, and wood technology.

In the State of Washington the 1947 legislature established the Washington State Forest Products Institute, with sufficient funds to survey the needs for forest research, and to make a report to the 1949 legislature. The advisory committee (the members of which are closely associated with the studies involved) have been studying four problems: (1) the need for a statewide survey of logging and manufacturing waste; (2) a clearinghouse for information on methods, equipment and costs of salvage logging, relogging and second growth logging; (3) market studies to determine the potential markets for fiberboard manufactured from waste in various forms; (4) basic studies relating to glue line strength and other properties in plywood and laminated wood.

Improved Utilization in the Woods and Its Effect on Present and Future Forest Management

Developments in the Douglas fir region definitely show that closer utilization before, during, or after logging greatly reduces the slash hazard by lessening the inflammable debris on the ground. If the slash is light due to the nature of the stand, no slash burning may be necessary. If the slash is normally heavy, close utilization will reduce the slash to a degree where its disposal by burning is not a serious problem and does less damage to the soil.

Douglas fir reproduces in dense stands; and early thinnings in the stand, followed by subsequent thinnings will salvage material that normally would be choked out. At the same time the growth of the remaining stand will be improved in volume and quality. Even though these thinnings only pay their way, they are justified by the stand improvement. The big problem today is to find markets for the thinnings.

In areas where selective logging is economically sound in more mature stands, markets for low grade trees permit the weeding out of these trees. This is particularly true in the Ponderosa and Inland Empire forests where white fir and other low-grade trees compete with the more desirable species.

Every managing forester recognizes the need for improving the forest, and looks forward to the day when through closer utilization, developed through research, he can remove from the forest those trees that do not pay their way.

In the past fifteen years the Pacific Northwest has shown greater progress in the utilization of its vast forests than in the fifty years preceding. With an alert public and private interest in forest products research, followed by better equipment and methods in the woods and mills, this progress will continue. All concerned are awakening to the fact that this is the last timber frontier; and only through wise and intensive use of not only the remaining virgin stands but also of the second growth, can the prosperity of the region be maintained.

Discussion

Dr. J. A. Hall (Pacific NW Forest Experiment Station): There is a lot of thinning going on in the Northwest. Much of it is experimental, but it is leaving a good thrifty forest. We are moving in the proper direction. There is a one-third increase in forest yield because of close utilization.

Mr. Drake: Commercial thinnings in the Douglas fir region are taking place today in areas where there is an active demand for pulp wood or smelter poles, such as in the areas around Tacoma, Longview, Port Townsend, and Hoquiam. In these areas due to the favorable markets and short hauls, such thinnings are possible.

The foresters look forward to the time when markets will develop that will permit thinnings in other areas. It has been found that the net volume of thinnings up to the time that the crop reaches the final stage may be equal to the volume of the final cut.

Mr. E. Fritz (University of California): In the case of redwood, the quality of sprout-origin trees is as good as that of trees originating from seeds, provided the stand was dense enough to cause the stems to clean themselves of limbs. Since sprouts occur in clumps, it is important that the forester gets copious seedling reproduction so that the gaps are filled in and a dense stand is attained.

Mr. Drake: I found in Sweden that their problems in regard to possibilities for thinnings was much the same that we are confronted with in the Northwest. If the timber is located reasonably close to the mills so that costs are within reason, thinnings can be carried on. The farther you get from the mills, the less intense the forestry practices, especially with regard to thinnings. The trends in Sweden to create markets for small material through the development of pulp and fiber mills has made possible better forestry practices. The same condition has developed in the Southeast and will follow in the Northwest.

Relation Between Wood and Pulp Properties

W. F. Holzer

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The fiber properties inherent in various species, the effect of decay on pulp quality, and the characteristics of the pulps obtainable from the Northeast, Lake States, South, and Pacific Northwest are described.

Introduction

THE first step in converting wood to paper is its reduction to fiber, either by chemical or mechanical means. In the first case the lignin of the wood is dissolved to liberate the fibers, and in the process much of the less resistant carbohydrate material is removed as well. In the second case the wood is literally torn to pieces, and the resulting pulp contains all of the wood except the water soluble portions. No matter which process is used, the fact remains that pulping is subtractive. We cannot make a pulp from wood, and end up with a fiber possessing some property not stemming from the parent material. True, we may control the properties of the fibers within limits by the type of treatment we use, but the final qualities are always inferior to the potential qualities in the original wood. From this the importance of the wood properties becomes obvious.

Both physical and chemical properties of the fibers in wood are important. In the first group the physical dimensions of the fiber, length, breadth, and wall thickness, and the crystallinity of the cellulose have significant bearing on pulp properties. The type and amount of hemicelluloses, coloring matters, and extraneous materials in the chemical makeup of the fibers help determine the papermaking properties. In addition to these qualities in sound wood, we must also deal with their modification by natural deterioration of the wood.

For purposes of discussion it is convenient to trace these properties as inherent to species, to growth type, and to wood condition.

Fiber Properties Inherent in Species

Hardwoods and Softwoods

The large difference between dimensions of fibers found in hardwoods (deciduous) and in softwoods (coniferous) is highly characteristic. In the former the woody fibers are typically one millimeter long, and 10 to 25 microns in diameter at the widest point. Tracheids of the latter are about 3.5 millimeters in length with a range from less than 3 to over 5 millimeters. Maximum diameters are in the range of 30 to 50 microns.

The dimensions of the softwood fibers are better suited to the manufacture of strong papers, with the result that these woods have furnished a preponderant percentage of the raw material. Due to their small dimensions, hardwood fibers are deficient by comparison in practically every strength property. This does not mean that hardwood fibers do not have some important papermaking qualities. Their small size promotes a uniform formation, increases bulk which improves opacity, and gives a smoother textured surface. All these properties are highly desirable in paper for printing, and strength is of lesser importance, with the result that there has been a small but steady demand for hardwood pulps in paper mills making various types of these papers.

In recent years the shortage of softwoods in some regions has forced the use of hardwoods for papermaking in increasing amounts. The hardwood pulps for printing papers have been cooked very soft by the soda process to enhance qualities of formation and texture at the expense of strength. This type of cook has masked to some extent the characteristic chemical property of hardwoods, that is the high hemicellulose content, by dissolving a large portion of this less resistant carbohydrate material. It is known that hemicelluloses and particularly pentosans tend to increase rate of beating, bursting and tensile strength, and transparency of paper.

Now that it is desired to add hardwood pulps to papers in which strength is of prime importance, the type of cooking has changed radically.

Normal sulfite and kraft cooks have improved strength over the soft soda cook, but the strongest hardwood pulps along with high yields are made from a neutral sulfite semi-chemical cook followed by bleaching. A large portion of the hemicelluloses is retained in the pulp resulting in a very rapid rate of beating, a bursting and tensile strength approaching that of softwood pulp, and increased transparency. Tearing resistance, which is dependent on fiber length, is low.

To date, this type of cook is largely confined to hardwoods, since it is slow in its lignin removal, and hardwoods contain considerably less lignin than softwoods. Here the wood properties have a bearing on the selection of the type of cook in addition to the type of pulp obtained.

Pulp Characteristics From Various Regions

There are marked variations in pulp characteristics by regions. It is recognized that these variations are due primarily to species, but it is interesting to speculate on whether differences in the climate and soil types determine the species to which certain physical and chemical characteristics are unique, or, whether under similar growing conditions, certain of these differences would tend to disappear.

The United States has four papermaking regions including the Northeastern States, the central section around the Great Lakes, the South, and the Pacific Northwest. For purposes of discussion, the first two may be considered as one since the wood species and their properties tend to be the same.

The papers from wood grown in the North Central and Northeastern States tend to be well-formed, to have good burst and tensile strength, but only fair tearing resistance, and to have good surface smoothness. Papers from woods grown in the Pacific Northwest have a less uniform formation, slightly less burst and tensile strength, but an excellent tear resistance, and a somewhat rougher finish than the first group. Papers from the South are nearly all kraft because the pulpwood is almost exclusively pine, but by comparison to similar papers in other regions, the formation again is somewhat non-uniform, burst and tensile strengths are rather low, but tear resistance is nearly equal to the western woods. Again the surface tends to be a little rough.

Fiber properties characteristic of the woods from the various regions are largely responsible for these characteristic variations of the respective papers. The best pulpwood of the North is black spruce. Its fibers are medium in length, averaging between 3 and 3.5 millimeters. The wood is slow grown so that diameters will run from 25 to 35 microns. These dimensions contribute to the good formation, good smoothness, and low tearing resistance. The good formation together with high hemicelluloses, which become fiber cementing material in papermaking, enhance burst and tensile strengths.

Western hemlock is the prime pulpwood of the Pacific Northwest, with Douglas fir attaining considerable importance in the last ten years. These woods and especially the latter have large fibers averaging nearly 4 millimeters in length and with large diameters ranging from 35 to 45 microns and even to 55 microns for Douglas fir. These dimensions account for the less uniform formation and the rougher surface, and are responsible for the exceptional tearing resistance of papers from that region. The woods and therefore the pulps are low in hemicellulose. This characteristic accounts for the slower development of strength as compared to northern and eastern pulps. In the case of Douglas fir this tendency is further enhanced by the very thick-walled summerwood fibers which detract from burst and finish, but make tearing resistance higher than that of any other papers made from wood pulps.

The fibers in the pines from the South are comparable to Douglas fir in dimensions and the paper characteristics are quite similar.

In color, the North and Northeast regions have the whitest woods and have the brightest pulps. The woods from the Pacific Northwest have a reddish cast, and the pines in the South are definitely yellowish.

Pulp Characteristics From Wood of Various Growth Rates

Data of Chidester and McGovern[1] have shown that faster growth wood will tend to have a slightly higher burst but considerably lower tearing resistance. They also pointed out the increase in percentage of springwood with

[1] Chidester, G. H., and McGovern, J. N. Paper Trade J. 106, No. 23: 37–39 (June 9, 1938); 107, No. 13: 24–29 (Sept. 29, 1938).

rate of growth. This is particularly true of younger trees.

Springwood fibers as compared to summerwood have larger diameters with thinner walls. Such fibers will flatten in the papermaking process, and make excellent fiber-fiber contacts and bonds that produce high burst and tensile strengths. Also these thin-walled fibers are not resistant to the cutting and bruising of beating and jordanning, and break up more than summerwood fibers, causing low tearing resistance.

Douglas fir is unique in the difference between its springwood and summerwood fibers. The differences in the pulp properties of these fibers were brought out in a study reported by Holzer and Lewis.[2] Springwood and summerwood were separated by hand and the two portions cooked separately. The springwood fibers, even unbeaten, formed into a smooth, hard sheet with high burst and low tear. As beating progressed, the burst rose rapidly and tear dropped to very low levels. The fibers were drastically cut in the process. Summerwood fibers, on the other hand, gave a very bulky, woolly sheet that had a very low burst, but an unusually high tear. These fibers were extremely resistant to beating with almost no evidence of cutting at the end. The physical tests showed correspondingly small change in strength in the process.

The walls of Douglas fir summerwood fibers are unusually thick, but their most unique property is the crystallinity of the cellulose itself.[3] This cellulose probably has the most highly oriented molecular structure found in wood, and aside from the thickness, or in addition to it, would be expected to be stiff, and difficult to form into a compact sheet.

Properties Inherent in the Condition of the Wood

Since papermaking depends on the individual wood fiber, it can utilize to good advantage logs that contain physical defects that make them unsuitable to other industries. Such defects as splits and breaks, roughness due to knots, crooked logs and the like, have little effect on fiber quality and need no further discussion. Overmature wood or salvaged wood which contain decay do have an effect on fiber quality. Along with the consumption of the woody material, the process of decay for our consideration involves the production of stain, and of organic acids that can act on wood at low temperatures but over long periods. The effects on the pulp are:

1. The color of the pulp is noticeably darker. This can be seen from wood where the deterioration is still in the early stages.
2. The acid of the products of decay acting over long periods makes the lignin more difficult to dissolve, probably through polymerization to larger, more inert molecules.
3. The cellulose is found to be degraded from acid and enzyme action, and in case of advanced decay very brittle and weak.

The correlation between degree of decay and effect on pulp quality is in the order named. The deterioration of pulp color is noticed along with incipient decay and persists through all degrees. The decrease in rate of cooking of wood is first detected when decay approaches an intermediate stage. The loss in strength of pulp may be detected earlier but does not become serious until decay becomes advanced, appreciable portions of the wood have been consumed, and the wood has lost considerable strength. Then, too, as the wood loses density, it becomes obvious that less can be charged into a digester of given volume, and the production per cook suffers proportionately.

In observing the effect of decay on pulp quality, results are sometimes confusing. That is, one lot of badly decayed wood may make fairly good and even almost normal pulp, while the next, showing much less decay, may yield a definitely inferior pulp. The explanation usually lies in the type of decay.

There are two main types of decay organisms, those classed as lignin-destroying rots, such as *fomes pini,* and those classed as cellulose-destroying rots, such as *Lenzites saepiaria.* By the time the wood is consumed, both types have been active but usually one or the other will predominate in attack until decay is well advanced. Which type will start first may depend on species or on local physical conditions, but a

[2] Holzer, W. F., and Lewis, H. F. Tappi 33, No. 2: 110–112 (Feb. 1950).

[3] Clark, G. L. Tappi 33, No. 2: 108–110 (Feb. 1950).

discussion of these factors is beyond the scope of this paper.

A lignin-destroying rot tends to leave the fibrous structure of the wood intact. The decayed wood being fibrous retains some of the toughness of the original wood, and "stands up" under the mechanical process of converting the log into chips. In so doing, it stays in the chips entering the digester, and the pulp is affected in proportion to the amount and degree of decay in the ways already described.

When wood is attacked by a cellulose-destroying rot, the fibrous structure is broken down, and a soft, crumbly material results. If the decay is well advanced, the affected portions tend to sluff off during the wood and chip preparation, and only the sounder portions enter the digester. For this reason pulp quality usually suffers less from a cellulose-destroying rot, especially one that tends to localize its action.

In all forest products industries the manufacturer must utilize the wood as he finds it. In many cases only the physical properties are significant. In pulp and paper manufacture the chemical nature of the wood also must be considered, and, since the process can tolerate an appreciable amount of decay, the effects of this defect are felt as well. After all, it may be best that, as the poet says, "Only God can make a tree", since none of us would care to accept the responsibility for the variations we find in the quality of our raw material.

Discussion

Mr. J. C. Robinson (Everett Pulp & Paper Co.): Can you make white paper from alder?

Mr. Holzer: Yes.

Col. Greeley (West Coast Lumbermen's Association): Why isn't there a larger market for alder pulpwood?

Mr. Holzer: Use of alder for pulp is a recent development.

Prof. E. Fritz (University of California): What is the effect of tannin in oak?

Mr. Holzer: There is a corrosive effect on digesters, which is thought to be caused by the tannins in oak. It is difficult to bleach oak pulp.

Mr. Eugene Tower (Forest Fiber Products Co.): Do you have any quantitative information as to the effect of amount of decay on strength properties in the finished products?

Mr. Holzer: Incipient decay has no effect on strength but does affect color. Moderate decay may effect the way pulp stands up on the paper machine. Pulp from wood with advanced decay develops strength rapidly in processing but breaks sooner in test.

Mr. Everett Reichman (Simpson Logging Company): What has been your experience in use of second-growth fir as a pulpwood, and how does the quality of the pulp from second growth compare with that from old growth fir?

Mr. Holzer: Second-growth is superior.

Mr. Reichman: What about difference between springwood and summerwood?

Mr. Holzer: Up to 40 year age growth rings are wide. The resulting paper has good burst and good tear—better than hemlock.

Mr. Joseph C. Robinson (Everett Pulp and paper Co.): Have you experimented with cedar?

Mr. Holzer: Yes, we have used it in kraft pulp. The wood is of low density. It is costly to pulp, since the light weight wood reduces digester capacity and the cedar extractives are corrosive to pulping equipment.

Mr. K. G. Chesley (Crossett Lumber Company): What effect does storage of pulpwood have on pulp yield? It is a major problem in the South. Is decay of stored pulpwood a serious problem in the Northwest?

Mr. Holzer: In the Northwest most of the wood is stored in water, therefore decay is not a serious problem. Trouble occurs only when storage is for an unusually long time. Effects of decayed wood on pulp yield are contradictory. It depends on the type of decay. Lignin-destroying decay leaves a fibrous residue that persists in chips into the digester and seriously affects pulp quality. Cellulose-destroying decay leaves a crumbly residue that sloughs off and does not enter the digester. Pulp quality is fairly good but there is a loss in yield due to sloughing of decayed wood. In any event, decay reduces wood density and lowers production proportionately.

Mr. Chesley: What about lodgepole pine?

Mr. Holzer: It is used in the kraft process and is a good pulpwood, giving a high yield. Pulp produced has a low tear, high burst and light color. The geographical location of lodgepole pine is poor.

Mr. J. C. Robinson: Do you use Cottonwood? *Mr. Holzer:* We use all we can get.

Power vs. Hand Falling and Bucking in Logging Operations of the West

E. P. Stamm

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The steps in the development of power logging are described and advantages of current methods cited.

Introduction

ONE of the most recent and outstanding developments in logging operations of the West is the use of power saws for falling and bucking. Within a short span of 15 years power saws have been so improved in design, weight, and efficiency that their use is rapidly replacing hand falling and bucking. This rapid change from hand to power falling and bucking has come about because of several reasons.

During the past several years there has been a steadily diminishing supply of timber fallers. The logging industry in the past has had to depend considerably on Europeans, particularly Swedes and Finns for hand falling and bucking with a cross-cut saw. As old experienced fallers and buckers have been dropping out of the industry or have taken less arduous jobs, young men in this present mechanical age have been unwilling to undergo the hard manual labor of hand falling.

Logging chances have steadily become more difficult as operations have moved back into the hills on to more difficult topography and into smaller timber with the result that the amount of timber a man can fall and buck manually per man-day has been steadily decreasing.

As a result of the scarcity of hand fallers and lower man-day production in falling timber, the logging industry has made a real effort to attract young men into the falling and bucking jobs by the introduction and use of power saws in the woods.

Early Methods

Although power saws have been undergoing trial for the past thirty years, the real progress has come within the last 15 years. Some of the early developments of power saw ideas as related by J. A. Addison[1] indicate the diversity of opinion as to how to fell trees mechanically. For example, a wire rope tree feller, which cut through the tree by heat of friction as it was drawn rapidly past the wood, was tried out. A rope saw was developed of fine two-way cutting steel rope. It was attached to a cable from a double drum and the rope was run rapidly back and forth from one drum to another, cutting the tree in passing. A red hot electrically charged wire was tried out to fell trees by burning through the wood. A device consisting of a series of augers which cut into the tree below ground level, thus eliminating the obstacle of stumps, was at least discussed but not developed. A power feller was developed, using a long roller equipped with cutting teeth mounted on the end of a driven shaft. It could swing in a horizontal arc and could cut its way through a tree. Many types of hand saws for timber felling were invented. The Russians designed an electric circular saw for this purpose. The French manufactured a circular saw for timber felling which was mounted on the front of a carriage. The saw was electrically powered but the carriage had to be moved by hand from place to place. A steam driven drag saw for felling and bucking was manufactured by the English. The boiler was mounted on wheels and was drawn by horses while the saw portion was carried by hand. The tree feller alone weighed 600 lbs. without including the boiler or the bucking outfit. None of these devices was even remotely practical for use in the West, and particularly the rough terrain of the Douglas-fir region. However, between 1930 and 1935 several types of portable chain saws powered by high-speed 2-cycle gas motors were

[1] "Latest Development in Logging Industry Solves Falling and Bucking Problems", by J. A. Addison. Bloedel, Stewart & Welch Ltd., Port Alberni, B. C.

tried out in England, Germany, Russia, and the United States, and, although they were apparently a failure due to light construction and motor failures, on test they did show some promise of better times to come, and by the year 1936, out of the welter of types and designs and trials of portable machines taking the place of the little man's muscle for cutting the big tree, emerged two definite types of machines which alone showed signs of promise and development into practical power saws. These were the drag saw and the chain saw.

The drag saw is successfully used in the California Redwoods where large size of the trees justifies the construction of a platform to set the heavy, cumbersome drag saw. In other regions of the West where a falling crew often cuts 50 to 75 trees per day—a tree every ten minutes—a chain saw light enough to carry from tree to tree and to operate from the ground is the only practical method of power falling. The first two power-driven chain saws on the market in North America were the Wolf saw, a very light-weight machine driven by either compressed air, electricity or gasoline motor, first developed during World War I; and the Dow saw, a heavy, cumbersome machine originally mounted on two rubber tire wheels. This latter saw did show promise of being reduced in size and weight for easy handling in the forests of the West and particularly the Douglas-fir region.

Current Methods

Now, in the course of 15 years, there are more than one dozen power saw manufacturers producing chain saws for the logging industry of the West. These chain power saws come in all sizes with blades and chain varying from 18 inches to 9 feet in length, and weighing from 25 to 135 pounds. Power saws are driven by either electric or gasoline motors with horsepower output ranging from 3 to 12 H-P. A recent achievement by the chain saw manufacturers is the development of one-man chain saws less than 40 pounds in weight and useful for falling and bucking and limbing, particularly in small sized timber.

Along with the phenomenal reduction in weight of power saws of all sizes has come greater speed in cutting and greater dependability and sturdiness of operation.

As a result of the fine saws available to the logging industry today, power falling and bucking is gradually replacing hand falling and bucking. The advantages can be summed up as follows:

1. Power saws have overcome the critical scarcity of hand fallers and buckers in the West by attracting young men mechanically inclined into this important phase of logging.

2. Power saw falling and bucking is safer than hand falling and bucking, which is one of the most hazardous occupations in logging. Power falling results in better undercuts and faster back cutting, less wedging and less use of the axe and springboard. Safety in use of power saws follows the old axiom "that a job done mechanically is safer than when done by hand."

3. Power falling and bucking is easier work for the individual.

4. Power falling results in increased man-day production and a direct saving in labor. This saving in labor, however, is offset in part by higher earnings, material, and maintenance costs.

5. The volume of felled and bucked timber kept in inventory ahead of yarding operations can be somewhat reduced in power saw operations, thus reducing the exposure of logs to fire, decay, stain, and insect damage.

6. Breakage is no greater in power falling than in hand falling. Experience is proving that power falling may result in less breakage because of lower stumps and of larger undercuts resulting in better control of the trees. Lower stumps cause less breakage in the skidding or yarding operations.

7. Greater yield of wood per acre is realized by the lower stumps in power falling. In small timber, for example, with 100 feet of merchantable length, a saving of 1 foot in stump height will result in an increased yield of almost 3 percent.

8. Increased production is realized from faster skidding and yarding as a result of fewer hang-ups in logging settings where stumps are cut low by power falling. Greater maneuverability of tractors and arches in the skidding operation is possible with low stumps.

9. In remote locations or at times of scarcity of labor supply the ability to produce a given

amount with a smaller crew with a power saw is an important advantage over hand falling.

10. Power saws make it possible to fall snags more cheaply and safely in fire hazard reduction measures. Cheaper and safer falling of insect and disease-ridden trees is also possible in control operations in infested stands.

Falling and bucking in a clear-cutting operation in the rugged topography of the Douglas-fir region amounts to about 20 percent of the total direct cost of logging. On smooth terrain in which selective logging of old-growth or thinnings of second-growth can be done, falling and bucking costs will play a major role in making partial cutting of stands economically possible. Power falling and bucking with all its advantages is making a major contribution in furthering intensive management of forests in the West.

Discussion

Mr. J. Alfred Hall (Pacific Northwest Forest Experiment Station): Does power falling equal hand falling in accuracy?

Mr. Stamm: Power falling results in better control, faster operation, and lessens damage to stand.

Mr. I. V. Anderson (Forest Utilization Service): By using a measure of work done, are power saws applicable to the South?

Mr. Stamm: Yes, with proper lightweight saws they will revolutionize operations in small timber.

Mr. R. C. Fraunberger (Philco Corp.): Can you give a cost comparison between hand and power saws on your jobs on a per thousand basis, including all costs—depreciation, maintenance, taxes, higher wages, etc.?

Mr. Stamm: Power sawing is two to three times more productive. With better training of operators, costs will come down.

Mr. Fraunberger: What is the spread of labor costs?

Mr. Stamm: The day hand rate in the area is approximately $1.80 per hour. Piece workers average approximately $2.20 to $2.40 per hour and in a few rare cases at some places as much as $5.00 per hour.

Col. Greeley (West Coast Lumbermen's Association): What has been your experience with human safety?

Mr. Stamm: There are fewer accidents per thousand man-hours.

Mr. Walter J. Ryan (Weyerhaeuser Timber Company): Have you used any circular power saws? These have been introduced into New Zealand and are proving successful for both felling and bucking in their planted forests.

Mr. Stamm: Crown–Zellerbach has tried some, but none were liked. They are considered too dangerous.

Mr. G. L. Drake (Simpson Logging Company): They have been tried in thinning. They are O. K. in open areas, but our ground is too rough in the West.

Mr. Corman (Weyerhaeuser Timber Company): How high are the stumps?

Mr. Stamm: Two inches from the ground. Tractors can go over the top of the stumps without any trouble.

Prof. E. L. Ellis (University of Idaho): What is done in your operations in regard to training and supervision of power-saw felling crews? The necessity of such action was pointed out in your discussion, but the question arises as to how this might apply in central Idaho where "busheling" by gyppos is the general rule on both marked and unmarked timber sales? Particularly on unmarked cutting of state and private lands much damage is often done to residual trees and felled trees by unsupervised crews—more than is usually found in hand-falling crews. Little supervision is given, and the choice of trees and method is usually left to the individual.

Mr. Stamm: An experienced hand faller is placed with an experienced power-saw faller and given the necessary training. When the trainee becomes proficient he goes on his own as a head power-saw faller. In this manner experienced hand fallers are given the necessary training. All of our falling and bucking work is closely supervised by a cutting foreman, assisted by scalers.

Mr. Edgar Mörath (Food and Agriculture Organization): In Austria power saws have a drawback in that new men in the woods do not want to operate them at first. Results have been good where power saws were in use. These saws are used whenever they can be afforded.

Mr. L. Mueller (Forest Utilization Service): Do you have any difficulty with power saws causing fires?

Mr. Stamm: I have heard of no fires started by power saws. A chemical extinguisher is supplied with each saw.

Prof. E. Fritz (University of California): Have you tried any ripping with power saws? It is getting to be common in the sugar pine and redwood regions.

Mr. Stamm: Yes, sled runners for skids and bridge stringers have been sawed.

Prof. Fritz: Did you use the same chain for ripping that you use for crosscutting?

Mr. Stamm: Yes, except that it was set obliquely. Oversize logs, such as spruce, are ripped in the river with power chain saws. It is cheaper to rip in water. It saves time and labor in turning the log.

Mr. F. H. Kaufert (School of Forestry, University of Minnesota): Do you feel that the use of power saws and other mechanized equipment will stimulate thinning or partial cutting in second growth stands?

Mr. Stamm: I definitely feel that the use of small one-man power saws in particular will be very useful in thinning second growth stands. There is no problem in directing fall of trees and very low stumps can be cut. Thinning operations at best are very expensive and we need to find cheaper operations.

Improved Methods of Handling Pulpwood

W. S. Bromley
Forest Engineer, American Pulpwood Association

The use of loading docks, winches, trucks and conveyors are considered in loading and unloading pulpwood by the piece. The Dixie Logger system of moving pulpwood on pallets is described. Several new methods of handling wood in bundles are outlined. The movement of pulpwood in the form of chips is briefly discussed. The need for more time and cost studies to weigh these various methods is stressed in concluding this paper.

Introduction

THE subject of handling pulpwood is regarded by pulpwood production men east of the Rocky Mountains as the most important activity in their field. This is the conclusion reached as the result of a questionnaire sent to the members of the four Technical Committees of the American Pulpwood Association to learn which of more than 20 phases of pulpwood production were most important. These representatives of pulpwood companies in the regions of the Appalachian Mountains, the Lake States, the Northeast, and the South, from Virginia to Texas, each had an entirely different order of priority of interest for their own region, with one exception. The men from each region were agreed that in their region and in all four regions combined the handling, in other words the loading and unloading, of pulpwood was the most important subject in the equipment handbook of the Association. In this handbook are posted the two to four releases issued each month on the latest developments in the mechanization of our industry. It is evident, therefore, that this paper on "Improved Methods of Handling Pulpwood" deals with a subject which is vital to the pulpwood industry of this country.

The job of getting pulpwood from the ground onto a dray, sled, truck or railroad car is essentially the same regardless of the hauling device being used for transportation of the wood. The methods followed and types of power used to get this job done vary considerably, but it is easier to consider improved methods in terms of whether pulpwood is being loaded by the piece, on pallets, in bundles or as chips.

By the Piece

In spite of the great progress made in mechanizing pulpwood production in the past ten years, the major portion of pulpwood is loaded by hand, piece by piece, in this country. That is why most of the pulpwood handled east of the Rockies is in lengths of 48 to 100 inches, with weights per stick of pulpwood such that one or two men can handle. Hand loading of pulpwood is undoubtedly the most inefficient and expensive means to use. It is not surprising that many ideas have developed to improve on this elementary approach.

The simplest device known to make piece loading by hand easier on men and more efficient is the loading dock or ramp. These docks are usually one or two railroad car lengths long, 4 to 6 feet high, and wide enough to permit a logging truck to drive onto the dock with the aid of a ramp approach as in Fig. 1. Loading docks are found most frequently in the Lake States where pulpwood is primarily 100 inches in length, and for this reason, has a heavier weight per stick than 4 or 5 foot lengths. More consuming companies, large producers and railroad companies should be urged to build such docks as they save as much as 480,000 foot pounds of manpower energy for every carload of pulpwood loaded from them. This should ultimately result in a savings of from $2.00 to $5.00 per car.

There are other simple methods of improving the technique of hand loading of pulpwood such as the use of hand hooks or grabs as used in the Northeast. The adoption of these aids are more a problem of training and human relations than that of mechanization or improved methods.

The simplest mechanized approach to loading pulpwood by the piece is found in the use of a cable on a winch mounted in the rear of truck cabs to pull heavy pieces or bundles of pulpwood onto the truck bed from the rear. A modification of this method developed by the West Virginia Pulp and Paper Company is shown in Fig. 2. It shows how the winch and cable are used to provide for loading trucks from the side of the truck bed instead of from the rear.

A refinement of truck powered winches can be noted in Fig. 3. It shows an "A" frame mounted at the rear of the truck with a swinging boom which supports the end block through which the cable runs. With this winch powered cable it is possible to lift large pieces or bundles of pulpwood clear from the ground beside the

Fig. 1.—Loading ramp. Fig. 2.—Winch-and-cable for side loading. Fig. 3.—"A" frame and boom loader. Fig. 4.—Powered-conveyor loader. Fig. 5.—Pulpwood pallets for rear loading. Fig. 6.—Type of pallet for wider load.

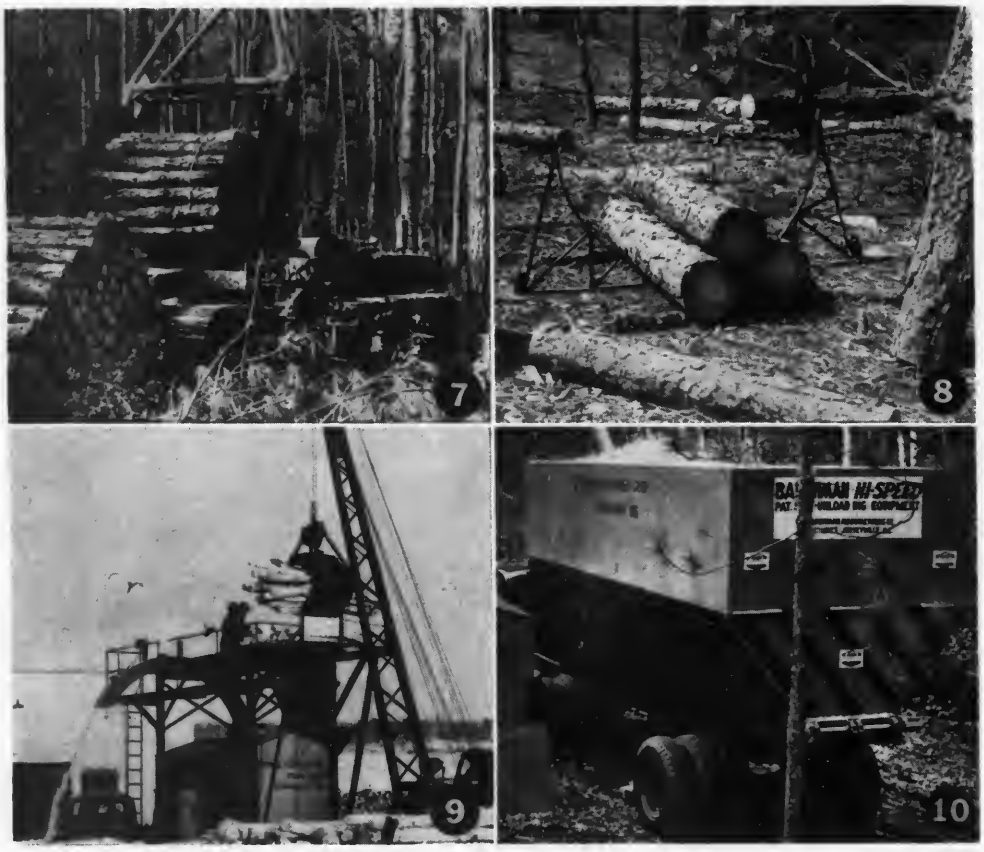

Fig. 7.—High-boom arch handling loaded sling. Fig. 8.—Loading frame to make up loads for shipping. Fig. 9.—Wood being chipped prior to hauling to mill. Fig. 10.—Special trailer unit for hauling chips.

truck. Then the force of gravity, by adjustments in the chain supporting the boom, is used to swing the boom so that its load will center over the truck.

Some progress is being made in using powered conveyors to load trucks and railroad cars by the piece. They consist of two general types. One is the end to end loading type as built by Bosworth Manufacturing Company of Cleveland, Ohio, and modified at the request of the West Virginia Pulp and Paper Company. The other is the side to side loading type which is the most common and widely used now as typified by the Montague "Cord a Minute" Loader shown in Fig. 4 and manufactured by B. L. Montague Company, Sumter, South Carolina. The latter is very efficient and can load as much as 40 to 60 cords of 5 foot 3 inch wood per hour if used to its full capacity.

On Pallets

The most significant development in improved methods of handling pulpwood in the South has been the increasing use of the Dixie Logger Pallet System. It consists of hand loading wood on pallets made by the Tidewater Equipment Company. Then trucks which are equipped with a winch to handle these pallets back up to the loaded pallet and pull it with one unit (160 cubic feet) of wood directly onto a special truck bed as shown in Fig. 5.

A recent modification of this system provides for hauling the pulpwood with the sticks parallel to the bed of the truck. In this way

trucks are loaded to their capacity as to legal width and better distribution of the load is obtained. Fig. 6 shows one unit of this type which was designed for the use of the Crossett Lumber Company. It has such a high gross vehicle weight capacity in its capacity of 6 to 7 cords that in many states it would be necessary to design a unit of lower gross vehicle weight or use a semi-trailer or full trailer unit in hauling maximum loads permissible under state laws, or to use back country bridges.

As one views the successful application of pallets in the South one cannot help but feel that it should be given more trials in the other pulpwood producing regions of the country. It represents one of the lowest investments in mechanizing pulpwood handling that any of the smaller producers might consider at this time.

In Bundles

The Pulpwood Industry is certain to give more and more consideration to handling pulpwood in bundles as they make it possible to move a larger volume per unit. In a well-balanced logging program, the operation which handles the larger unit is certain to have the lower costs per ton of material handled. The bundling of wood requires the use of heavier machinery to handle the larger units. This in turn demands greater capital expenditures than most producers of pulpwood care to invest. For this reason the bundling of pulpwood has been confined to a relatively small number of companies and essentially no independent producer operations.

One of the most successful large-scale loose bundling operations in the East is that of the International Paper Company at Georgetown, South Carolina. On these operations 5-foot-3-inch wood is piled close to the cutting in units of 160 cubic feet. These are lifted and moved in slings by a high boom arch as shown in Fig. 7. The loose bundles of wood are hauled directly to semi-trailer units on woods roads and neatly piled onto trailers through use of the "Busch Sling" described in Release No. 25 of the Equipment Handbook of the American Pulpwood Association. At the wood yard the entire trailer load of 6 to 7 cords (128 cubic feet) is lifted by large cranes which through the use of the Busch Sling deposits this large loose bundle in a neat pile that is satisfactory even for storage on a barge, onto cars, or in the wood yard.

Close to Georgetown, South Carolina, the West Virginia Pulp and Paper Company is experimenting with the handling of pulpwood in tight bundles of 80 cubic feet each. These are made up on the scene of the cutting from 5-foot-3-inch wood by forming a circular pile on light frames as shown in Fig. 8. Two steel band straps of 3/8-inch by 0.050 inch material are tightened by a hand device of the Acme Steel Company, Chicago, Illinois. The resulting bundles are then moved to and loaded on trucks by a high boom arch such as noted above, or a modification of this unit which was designed by the West Virginia Experimental Forest organization at Georgetown, South Carolina.

The most advanced development in the handling of pulpwood in tight bundles is the long or tree-length packaging conducted on West Coast operations.[1] It is to be expected that this use of a large size package would be regarded most favorably there because of the large scale of the operations and the presence of heavy equipment. So long as the Western region has the heavy trucking and loading equipment in use for the handling of sawlogs in lengths from 16 to 40 feet or longer it is likely that it will be practical to use this same equipment for hauling long lengths of pulpwood in packages. It does not seem that this method of handling pulpwood is likely to get much consideration east of the Rockies, so long as operators here secure the major portion of their wood supply from independent contractors and operators who rarely have more than a single tractor of 25 to 35 hp. and a conventional truck or two of the 1¼- to 2-ton capacity.

As Chips

The most radical development in the handling of pulpwood is that of chipping the wood in or close to the woods and hauling it to the mill as chips. This procedure has been initiated on a trial basis by the National Container Corporation at Tomahawk, Wisconsin and is described in Release No. 73 of the Equipment

[1] De Moisy, Ralph. Packaged Logs. New Wood Use Series, Circular No. 6, Forest Products Institute, Seattle.

Handbook of the American Pulpwood Association. The advantages cited for this method of handling pulpwood are:

1. It permits closer utilization of the trees felled by using wood to as small a top as two inches in diameter. It should encourage thinning and utilization of material from second growth stands which could not be cut under most circumstances.

2. The fire hazard in forest stands is lowered because the amount of slash is reduced by closer utilization.

3. Storage in mill yard and subsequent losses from decay are eliminated when the chipper is in operation.

4. The handling of wood in a wood room of the mill is eliminated. All these advantages may result in a saving of as much as $1.50 per cord on the cost of chips delivered to the pulp mill. Against these favorable considerations the following limitations must be regarded:

1. At present only rough poplar is being used and the chips developed are used in a semi-chemical pulping process where the proportion of bark left on the chips is not serious.

2. The largest diameter this chipper will handle is 12½ inches, and it is fed from the top as shown in Fig. 9.

3. Full integration of production of pulpwood in the woods and the hauling of chips to the mill is required and weather conditions may seriously disrupt this in the Lake States.

4. A specialized form of trailer or truck unit as shown in Fig. 10 is required to haul the bulky chips which take up close to twice the volume of a similar weight of wood.

Conclusion

No attempt will be made here to evaluate the relative advantages or disadvantages of hauling pulpwood by the piece, on pallets, in bundles, or as chips. Each company must regard these procedures in the light of its entire capital investment, wood resources, and operating methods from stump to chipper. Decisions as to the most efficient and most economical methods must be based on experience, trial and error, and careful time and cost studies. The pulpwood industry as a whole is not making adequate use of time and cost study techniques in the production of pulpwood. These techniques have for years been used in analyzing pulp mill operations. The fact that so much of the pulpwood is produced by operators who are not under control of the pulp producing companies has retarded the use of time studies in the woods. Ways and means of making these studies in spite of the reluctance of the industry to interfere in any way with the contractual relationship it may have with independent pulpwood producers must be found. Until they are, the industry is likely to progress very slowly in deciding whether it should be using 4-foot, 5-foot, 8-foot, log-length, or tree-length material or whether it should be moving pulpwood by the piece, on pallets, in bundles, or as chips.

The current improved methods of handling pulpwood have been reviewed, but the question of which method is best for your operation can only be determined by your experience, costly trials and errors, or carefully planned, well financed, and adequately staffed cost and time studies.

Discussion

Mr. P. N. Vance (Fir-Tex Insulating Board Co.): What methods of barking are used in portable chipping operations located in the woods?

Mr. Bromley: Most of the bark is removed from the wood during the chipping process. Some means of removing bark chips from wood chips is needed.

Mr. G. L. Drake (Simpson Logging Company): Isn't poisoning of trees to loosen bark being done?

Mr. Bromley: Yes, it is becoming popular. Trees are marked, girdled, and poisoned. The bark falls off later. Sodium arsenite is used.

Col. W. B. Greeley (West Coast Lumbermen's Association): We have a man present who has just returned from observing tree poi-

soning methods in Pennsylvania. I would like to hear his comments on costs and the methods used.

Mr. Ralph DeMoisy (Washington Institute of Forest Products): On the Armstrong Forest Company holdings the poisoning of trees on a commercial basis costs 40 cents per cord as compared with $1.50 to $3.00 for hand or machine de-barking. Combined action of the poison and handling during transportation removes most of the bark. Trees are girdled and the poison in liquid form is painted on in a 6-inch belt where it is absorbed rapidly.

Col. Greeley: How does the American Pulpwood Association carry on its mechanization program?

Mr. Bromley: Through the discussions and activities of its five Technical Committees and by keeping its members posted on new equipment and methods of producing pulpwood; through the releases published in its Equipment Handbook and Training Manual.

Mr. L. A. Mueller (Forest Utilization Service, Northern Rocky Mountain Forest Experiment Station): Is bundling of pulpwood on the increase in the East?

Mr. Bromley: Yes, it is getting more consideration, especially since the 75-cent minimum wage law went into effect. Hand labor was feasible before, but now many operators will have to use more machines and larger packages in handling pulpwood.

Mr. T. E. Kelley (Washington State College): How do you suggest the pulpwood industry be kept fully informed as to new developments in the mechanization of pulpwood production?

Mr. Bromley: By exchanging ideas and information through bulletins and our Equipment Handbook and by discussions and demonstrations of this type and the Technical Committees of the American Pulpwood Association.

Mr. A. Stuart (Industrial Consultant, Portland, Oregon): Are there any published comparative cost studies on pulpwood handling methods?

Mr. Bromley: Very few, and that is a weak point in our progress now. There is a lack of economic studies. Methods of accounting vary, and a standard system of cost control and cost accounting is needed. Little is available in this field as far as woods operational records are concerned.

Mr. Stuart: There is a great advantage in making this information available to the public, and to pulpwood operators.

Mr. Bromley: Much of our material on training and mechanization is made available to forestry schools and interested government agencies. To reach farmer operators and small pulpwood producers, the cooperation of the Extension Service in problems of logging, moving, and transporting of wood is likely to be helpful. The American Pulpwood Association is reaching an increasing number of pulpwood producers and workers each year through its mechanization, training and safety programs.

TECHNICAL SESSION IV

Tuesday, June 27, 1950, 9:00 A. M.

General Subject: Quality Control in Forest Products

Chairman: R. C. Fraunberger, Philco Corporation, Philadelphia, Pennsylvania

Recorder: Raymond H. Dingman, Chief Instructor, Klok Institute, Grand Rapids, Michigan (Secretary-Treasurer, Grand Rapids Section, FPRS)

R. H. Dingman, R. C. Fraunberger.

FOREST PRODUCTS RESEARCH SOCIETY

Quality Control in Sawmill Operations as Practiced in Class 'A' Douglas Fir Mills

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The problem of quality control in lumber manufacture is complicated by the great variation in raw material quality, and by the fact that so many thousands of producers, many with no stake in the future of the industry, are engaged in lumber production. A discussion of the quality control practiced by Class A Douglas fir mills of the Pacific Northwest should reveal some effects of these complications, and emphasize the need for greater industry-wide interest in quality control.

Even the quality control practiced by Class A fir mills varies widely among the 160-odd plants in this group. Some of these mills pay strict attention to all phases of quality control including: (1) the adjustment of manufacturing methods to the quality of logs available, (2) an emphasis on maximum value recovery at each stage of manufacture, and (3) the expenditure of time and money on product improvement. Others stress quantity production, overlook losses of value in manufacture, and devote little effort to product improvement. Despite this disparity, all Class A fir mills must consider quality to some degree.

QUALITY control has been defined in many ways. As applied to lumber manufacture it means, "Obtaining the highest possible value from every log cut." This implies such things as:

1. Proper log selection for a given mill or the adoption of manufacturing methods that are suited to the log supply available.
2. Maximum value recovery and minimum loss from each log sawed through control of the individual operations.
3. Maintenance or improvement of product standards in order to hold or expand markets in competition with other manufacturers.

In general, the lumber industry has done a better job of adapting manufacturing methods to log supply than it has in reducing losses or in expanding markets through product improvement.

Any discussion of quality control in sawmill operations involves the danger of generalization. More than 50,000 sawmills contribute to the domestic lumber production. The problem of quality control differs for each of these manufacturing units for no two are identical with respect to quality of raw material, manufacturing equipment, skill of the labor employed, and markets supplied.

For example, the Class A Douglas fir mills of the Pacific Northwest as a rule are quality conscious. Class A fir mills are those cutting principally Douglas fir and at a rate of more than 10 M. bd. ft. per hour. This class includes about 160 mills, roughly ten percent of the sawmills in western Oregon and Washington, and accounts for approximately 55 percent of the lumber production of this area.

The fact that these mills are selected for discussion does not imply that all of Class A mills are more efficient and progressive than any of the class B, C or D mills of the region. But by and large, because of larger investments, greater working capital and a greater variety of specialized equipment; this class includes a group of stable and efficient producers.

Quality Control Through Log Selection

The problem of log selection for Douglas fir sawmills, which was relatively simple and under complete control of the lumber manufacturer during 1930's, has assumed critical importance due to the diminishing supply of old-growth timber and the growing demand for all types of forest products from the Pacific Northwest.

The problem of log selection has at least three phases:

1. There is increasing pressure on fir sawmills to accept some marginal or submarginal logs.
2. Increased markets for peeler logs and pulp logs make it more difficult to decide whether a particular log should be peeled, pulped, or sawed.
3. It still is desirable to sort logs by sawing characteristics providing that sufficient pond space is available.

Marginal or Submarginal Logs

The commendable improvement in timber utilization in the Douglas fir region during the past ten years has posed a new problem for fir sawmills. In recovering a 20 percent greater volume per acre from many areas, loggers include shorter, smaller, and more defective logs than they did in prewar years. In many instances the strong demand for forest products has made it possible to process this material at a profit.

Based on these profitable experiences, loggers, logging departments of pulp companies and many lumber manufacturing concerns, and the agencies responsible for federally-owned timber are applying closer standards of utilization in the woods. Although the logs recovered are merchantable (containing at least one-third sound wood), they may be submarginal for many sawmills. Partially defective logs, particularly Douglas fir logs containing white pocket rot, vary considerably in their suitability for lumber production for not only the amount but the location of the defect is important.

The seriousness of the submarginal log problem lies in the fact that such large volumes of these logs are diverted to sawmills. Three factors contribute to this situation. First, there is a tendency to practice closer utilization on private lands due to higher investments in stumpage and logging roads. Second, between 10 and 15 percent of the old-growth logs sawed in the region come from federally-owned timber stands where close utilization is required. Third, although many of the submarginal logs could be converted to pulp for container board, hardboard or similar products at a profit, these outlets are limited at the present time.

The large volume of low-grade logs now processed by sawmills is reflected by an increased production of No. 3 and 4 common lumber. The proportion of No. 3 and 4 common produced in western Oregon and Washington runs as high as 25 percent compared with approximately 10 percent in prewar years. The production of cut stock and end-matched material, better trimming for grade, and more aggressive merchandising have alleviated the problem but have not solved it.

Selection of Logs for Sale

Plywood plants now offer premium prices for logs that formerly were considered sawlogs while pulp mills accept low-grade Douglas fir logs more readily than in the past. Thus, lumber manufacturers who do their own logging face a problem of log disposition. They must decide whether certain types of logs will yield a greater profit through sale to plywood or pulp mills, or whether they will yield a greater profit through sawing. Fluctuations in log prices and in lumber inventories may require frequent reappraisals of comparative log values.

Mill Studies as an Aid to Log Selection

On occasion Class A fir mills resort to mill studies in order to check comparative log values. A typical mill study involves cleaning the mill and sorting chains; sawing a certain type or grade of log, say No. 3 peelers, for 8 hours; then tallying and grading all of the lumber recovered. A study of this type is adequate for logs of fairly uniform quality. It is not too satisfactory for partially defective logs owing to the wide ranges of variability encountered.

For defective logs which exhibit wide variation in the character, extent, and location of defect, it is desirable to follow each individual log. The School of Forestry and the Oregon Forest Products Laboratory recently have participated in two mill studies of the latter type. Such a study not only reveals which logs are sawed profitably but shows the margin of loss on submarginal logs. In this way, the study indicates the possibility of sawing some types of logs profitably by varying sawing procedure or by seeking new market outlets. In addition, it provides a basis for better log selection in the woods.

Sorting and Storage of Logs

If the sawmill log pond is large enough, it is customary to store some classes of logs for sawing at a later time. Species such as hemlock and cedar are often stored in the pond until the mill can make a full day's run on one of these species. This practice makes it possible to concentrate on cutting orders and manufacturing practices appropriate to that species.

Douglas fir logs suitable for the production of such items as long, high-quality timbers may

be held in the pond until orders for such timbers are received. This means that these logs may return their maximum value in special cuttings rather than the average value realized from stock items. Inquiries for special cuttings are often rejected by fir mills when suitable logs are not available. Attempts to cut special timbers from average logs may result in decreased production, a high percentage of rejects, which require costly remanufacture, and dissatisfied customers.

It is evident that quality control in lumber manufacture begins with log selection in the pond or in the woods. Raw material quality is so variable in the Pacific Northwest, particularly when partially defective logs must be sawed, that Class A fir sawmills face a particularly complex problem.

Quality Control in Manufacturing Operations

Quality control after log selection involves: (1) the installation and maintenance of suitable equipment; (2) thorough training of key employees, and (3) adherence to manufacturing practices that will yield maximum values with minimum losses. Instead of discussing each of these factors separately, the stages of lumber manufacture will be covered in sequence, describing the quality control measures applied at each stage.

Head Sawing

Equipment. The main or head sawing operation in Class A Douglas fir mills normally is accomplished with an 8- or 9-foot band saw, although some double-circular head saws are used. Careful attention is given to saw alinement, saw speed, rate of feed, saw strain, and saw filing to avoid "snaking" of the saw and an unnecessary variation in lumber thickness.

Carriages are, as a rule, large enough to take logs up to 6 feet in diameter and 40 feet in length. They usually are provided with electric setworks having a preset arrangement to insure accurate setting to $\frac{1}{32}$ inch, and have automatic taper setting equipment. These carriages, weighing up to 40 tons, must be maintained constantly to insure perfect alinement and accurate setting.

Sawyer training. Mill men state that it costs $10,000 to $15,000 to break in a new sawyer. This probably is a conservative estimate of the cost to a Class A fir mill. Some of the cost is due to a temporary decrease in production; most of it is due to the loss of values incurred while the new sawyer learns the characteristics of the mill's log supply and the manufacturing practices of the mill.

A sawyer must handle the carriage, log loader and log turner safely but without hesitation for he is the mill's pacemaker with 30 to 100 men gearing their production rate to his. As a rule, the head saw is capable of swamping the rest of the mill with lumber by sawing at maximum speed. This means that the experienced sawyer need not concentrate solely on speed, but can give attention to log quality and special cutting orders on hand.

As L. A. Nelson,[1] has stated, "The sawyer's responsibility is to break down the log in accordance with operating policy, as rapidly as possible consistent with quality recovery and do it with a minimum of waste. His ability to think clearly and to decide quickly is reflected in a large output of good quality lumber". Since the quantity and quality of lumber produced is determined largely by the head sawyer, the training of a sawyer is a matter of utmost importance.

Manufacturing practices. It is customary for the mill management to furnish the head sawyer and other key men with general sawing instructions. In Class A fir mills, sawyers usually are instructed to cut for the highest quality the log will produce. However, this general instruction may be modified by special cutting orders and the balance of lumber stocks on inventory.

With quality production in mind, many Class A fir mills instruct the head sawyer to taper saw all logs—cutting parallel to the bark. Other Class A mills may leave this to the sawyer's judgment expecting that he will taper saw logs of better quality, especially if they are butt logs or long logs. The chief advantage of taper sawing is that it produces straight-grained lumber from the best portion of the log. This straight-grained lumber not only has higher strength and initial monetary value but suffers less degrade in seasoning and planing.

[1] Nelson, L. A. 1948. Sawing Logs Into Lumber. Timberman 49 (5):84.

Taper sawing consistently gives a higher quantity recovery or overrun per M board feet of log scale. This additional overrun compensates for the time required to set the log properly on the carriage. Therefore, the added value of the lumber recovered by taper sawing represents increased profit.

In deciding upon the thickness to cut at the head saw, mill managers are guided by experience. Factors that will determine cant thickness include: (1) the accuracy of the head sawing, (2) the kerf, sawing accuracy and the number of cuts to be made by the resaws, (3) the shrinkage allowance, if the lumber is to be kiln dried, (as determined by the average moisture content desired), and (4) the allowance needed for planing without a loss in grade due to skips.

If it is possible to state an average sawing practice for Class A fir mills, it might be said that the average practice is to cut common cants to net sizes, (2-, 4-, 6-, 8-inch, and greater thicknesses), and Clear or shop-type cants 1/8 or 1/4 inch oversize. Clear and Shop are resawed more often, dried to lower moisture contents, and need to surface out cleaner to stay on grade. Consequently, heavier thicknesses must be cut at the head saw.

Cant thicknesses for special cutting orders such as timbers, railway car material, battery separator stock, etc. are determined by mill experience. When a head sawyer is cutting cants for special orders as well as Common, Clear, and Shop for stock, confusion may result in the later breakdown of these cants. Differences in cant thickness may be very slight. The sawyer has anticipated what each cant should produce as it passes through the mill, but his anticipated breakdown may be misunderstood by the edgerman, trimmerman or resawyer. Although each key man in the mill has a duplicate list of special orders he may be so pressed to keep pace with the head saw that he will saw a cant improperly.

In most mills, the head sawyer is able to signal his anticipated use of a cant to other key men in the mill by means of lights or horns. In rare instances, an intercommunication system may be employed for this purpose. As a rule, the routing and remanufacture of cants according to the head sawyer's intention could be improved upon with a saving to the mill. However, such devices as intercommunication systems have disadvantages and most mills rely on the experience and interest of their key employees to avoid undue losses through misinterpretation of the sawyer's intentions.

Cant and Timber Trimming

In long-log mills having a variety of remanufacturing equipment, cants may be routed from the head saw directly to a push-button station and cut-off saw. The cut-off saw is operated by a man familiar with cant grading who can trim long cants and route the two or three shorter pieces to the proper place in the mill—preferably to the pony resaw, gang resaw, edger, or timber dock.

In Class A fir mills that have only one or two resaws, the above functions may be performed in part at the timber cut-off saw. The duty of the cut-off saw operator is to trim timbers to order and return pieces too short for timber orders to the proper place in the mill. The cut-off saw operator is responsible for checking timber grades against orders. If a piece is not up to grade, it can be rerouted immediately. This practice limits later rejections, extra handling in the yard, and the necessity of last minute cutting to complete a special order.

Edging

The function of the main edger, which is located near the head saw, is to rip cants as intended by the head sawyer. Duties of the edgerman include edging slabs for later resawing, ripping cants into special or stock items, removing wane with minimum loss, and segregating Clear from Common in the ripping operation.

This is an over simplification of the edgerman's responsibilities for he must be alert for special-order cants, ever conscious of grade characteristics, and must maintain a uniform pace so that he may position the cant and set the edger saws accurately without delaying the head saw.

Equipment. The main edger is built for stamina. Delays at the edger will slow the head saw almost immediately in most Class A fir mills for there is little storage space between these two pieces of equipment. In order that the edgerman may keep pace and still have

time to cut for maximum value, the edger usually is equipped with variable-speed feed rolls, double transfer chains, and often has shadow guides lines cast on the front edger table by overhead wires. At least two pine mills have installed shadow guides that move with the saws. While this type has not been installed in fir mills, some Class A fir mills are considering the addition of such equipment.

Edgers should have ample power, sharp saws and well-maintained feed rolls to assure straight feeding. Weaving of edger saws or crooked feeding of cants can cause serious losses of high-grade material. Many Class A fir mills have adopted a mechanical device to hold square-edge cants against the edger guide. Holdover devices are helpful, as cants with one square edge are more apt to saw crooked, but they will not compensate for worn feed rolls or dull saws.

Manufacturing practices. Although the mill manager provides the edgerman with certain general instructions and supplies him with copies of special cutting orders, in the main the manager relies on the edgerman's experience, judgment and interest for quality control. A serious obstacle to maximum recovery in edging is the limited storage space ahead of the edger. Once this is filled, the edgerman must work under pressure. A study made years ago revealed that the edgerman could spend only 18 percent of his time in examining cants as a basis for his sawing pattern; the balance of his time was required for spotting, saw setting, feeding, transferring, etc. It is believed that present mill practice allows very little more time for this important phase of an edgerman's work.

It has been suggested that an intermediate cut-off and grading station be installed between the head saw and edger in mills that have no provision for cant trimming ahead of the edger.[2] Doubtful cants, which require trimming or special consideration to decide the most desirable cutting pattern, could be shunted to this station. An experienced grader would trim where necessary, mark for ripping, and route the cants to a position near the edger feed table. The edgerman, if relieved of such responsibility, could maintain the mill's production rate without sacrificing quality.

Gang Trimming

Gang trimmers, which are used almost universally in Class A fir mills, are very efficient production machines but have little to recommend them in so far as quality control is concerned. Mills cutting over 6 M board feet of lumber per hour usually employ gang trimmers in order to maintain production on a straight line basis. From the standpoint of obtaining maximum recovery, gang trimmers have two disadvantages. First, saws are set two feet apart and cannot remove a defect without an unnecessary loss of material. Second, the trimmerman is some distance above the lumber and unable to see defects as well as he could in hand trimming.

A majority of Class A fir mills have eliminated slasher saws from their plants. The cutting of edgings, slabs and non-merchantable pieces into four foot lengths is done instead on the gang trimmers. This means that the trimmerman, a key employee possessing a knowledge of lumber grades and values, sees each piece before it can be consigned to the waste conveyor. This in itself is a forward step in quality control for there is always a tendency for off-bearers behind the head saw and edger to divert too much material to the slashers when the trimmer table becomes congested.

The elimination of the slasher, however, places a heavier burden on the gang trimmer. Unless the mill has a very smooth flow of lumber, this may contribute to pile-ups on the trimmer table. During such periods, the trimmerman may have insufficient time to trim high-quality pieces for grade.

In some Class A fir mills, lumber that has been resawed must be returned to the main gang trimmer. This arrangement throws an especially heavy burden on the trimmerman. A majority of the resawn lumber does not require trimming, and it is helpful if pieces that do not need retrimming can move directly to the green sorting chain.

Retrimming

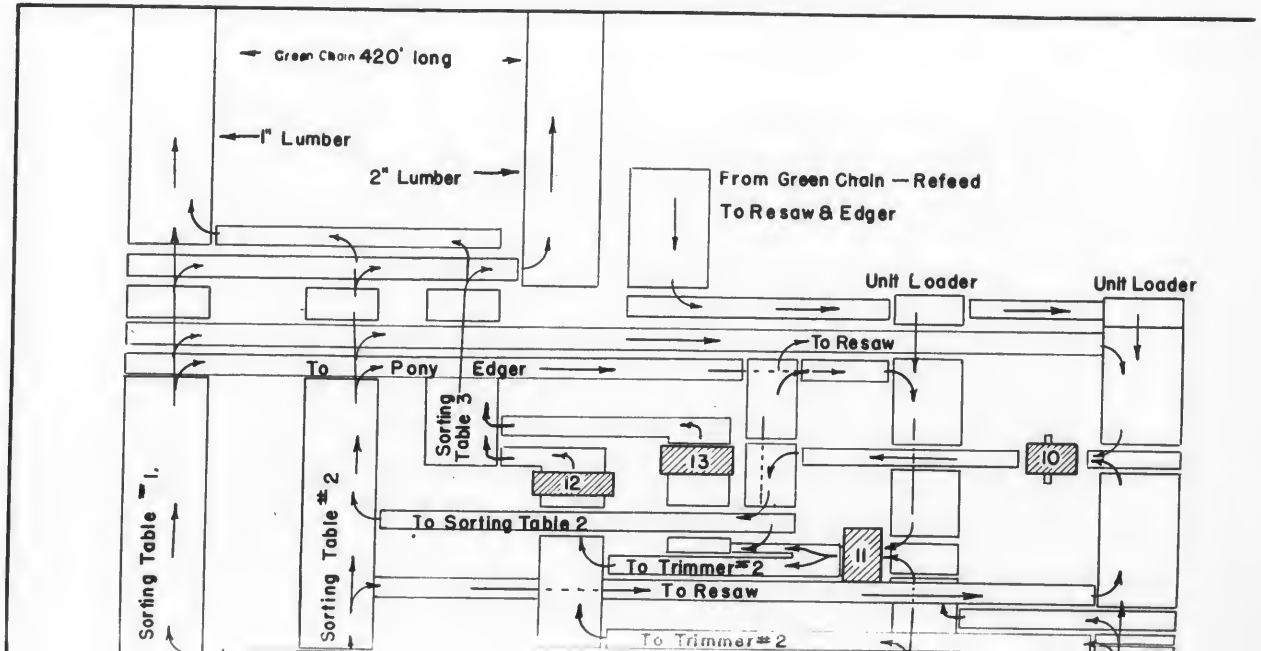
Where Class A fir mills have more than one piece of resawing equipment, an additional

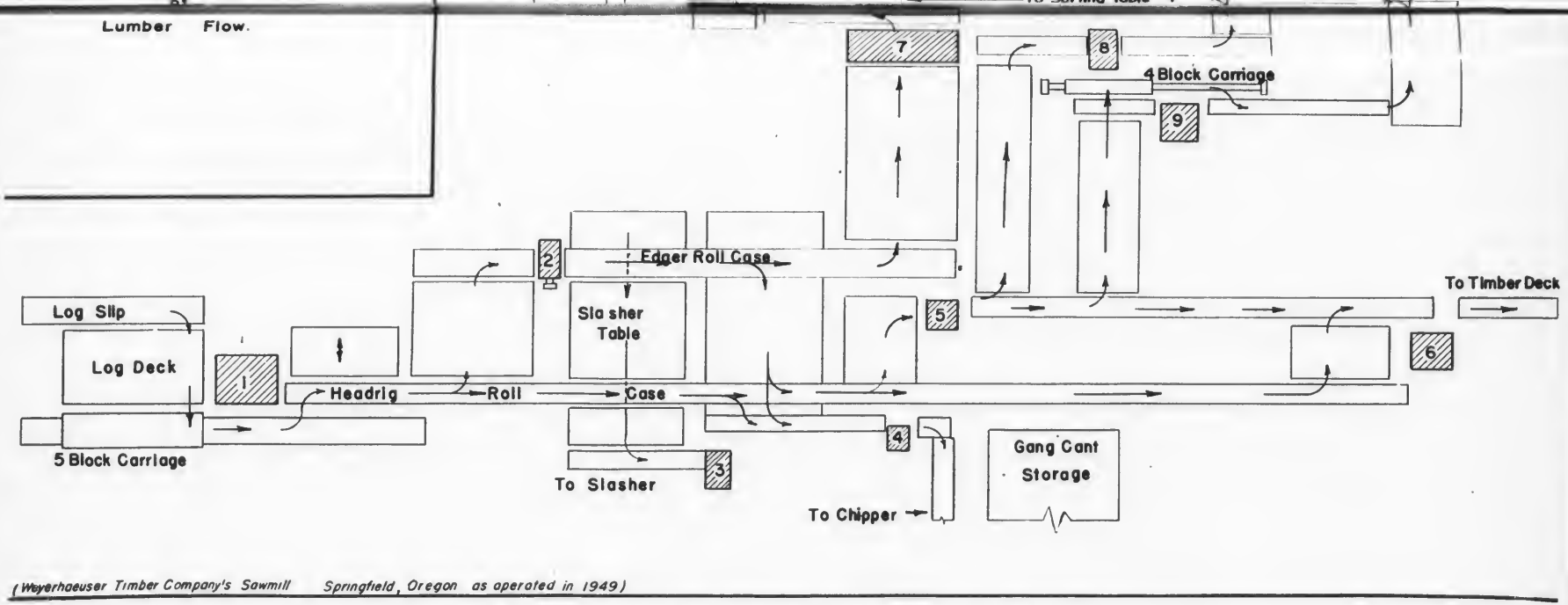
[2] Mitchel, W. F. 1949. Design for Sawmill Floor Plan. West Coast Lumberman 76(1):102.

Sawmill Equipment

1. Headrig
2. Main Edger
3. Automatic slasher cut-off saw
4. Pulp wood cut-off saw
5. Cant trim saw
6. Timber cut-off saw
7. No. 1 Trimmer — 42 feet
8. Gang resaw
9. Pony resaw
10. Horizontal band resaw
11. Pony resaw edger
12. No. 2 Trimmer — 24 feet
13. No. 3 Trimmer — 24 feet

Arrows Indicate Direction





(Weyerhaeuser Timber Company's Sawmill Springfield, Oregon as operated in 1949)

Fig. 1.—Equipment arrangement in a large Class A Douglas fir sawmill.

gang trimmer normally is required. This secondary or pony trimmer will handle stock from the resaws and re-edger. Inasmuch as pony gang trimmers normally will handle stock only 20 to 24 feet long, the pony trimmerman must exercise care in trimming for grade lest he produce an excessive amount of short-length lumber. Ten to twenty percent of lengths less than 8 feet can be included in most clear grades without loss of value but some short lengths will be produced in the planing mill. Excessive amounts of short-length lumber must be sold separately at a heavy loss. Thus, an excessive production of shorts will defeat the purpose of trimming for grade.

Undue congestion ahead of the pony trimmer is sometimes relieved by installing a hog beside the transfer chains leading to the pony trimmer. Edgings, shims or other pieces with no further value can be pulled and fed to the hog so that the pony trimmerman need not sacrifice time in cutting these on the trimmer.

Resawing

A major problem of quality control in sawmills centers around the choice of resawing equipment. The selection and arrangement of resaws will depend largely upon the quantity and quality of logs available to a mill.

Resaws may accomplish four purposes:

1. They may increase the production of the mill.
2. They may lower the average cost of production.
3. They may increase the volume of lumber recovered from each M board feet of logs sawed.
4. They may increase the average lumber value.

No mill can recover maximum value from old-growth Douglas fir logs without some type of resaw. The type of resaw, or resaws, selected may determine whether or not the mill can obtain the maximum value from a given class of log. Unfortunately, only a few Douglas fir mills are large enough to justify the installation of each type of resaw and many Class A mills must depend upon one machine to perform all of the resawing operations. The characteristics of the four major types of resaws are considered below.

Gang resaws. Gang resaws provide the only means of producing an appreciable amount of vertical-grain lumber at Douglas fir mills. For this reason alone, a gang saw is warranted in any large fir mill cutting old-growth logs. Vertical-grain stock brings a $20–$25 per M board feet premium over flat-grain in B & Btr and C-Select grades. Consequently, wherever a Class A fir mill includes a gang resaw, the head sawyer strives to cut clear cants that will produce vertical-grain stock on the gang. A gang resaw also permits a mill to cut such high-value, specialty items as ship decking and battery separator stock to good advantage.

Gang resaws possess the further advantage of sawing very accurately. Although a gang resaw takes about the same kerf as a band resaw, it does not require as much allowance for sawing variation. Consequently, large cants may yield a greater footage of lumber when cut on a gang.

Gang saws do require cants of uniform quality for efficient operation. However, where a mill is cutting large, defective logs, the gang resaw provides a means of producing boards from the defective portions of such logs at a very reasonable cost.

Horizontal band resaws. A horizontal band resaw is the most satisfactory type for resawing slabs as the slabs lie flat on the resaw feed bed. The feed bed normally is divided and supplied from two sides making the horizontal band a high production machine when settings are standardized. Most mill men consider this machine less versatile than the vertical band and few mills install a horizontal band unless a vertical band is available.

Vertical band resaws. A vertical band saw will perform most resawing operations although it will not perform some as well as the horizontal band, and cannot efficiently perform the major function of a gang saw.

Several recent improvements in vertical band feed mechanisms make it possible to feed saws faster and more accurately. Accurate sawing, however, depends first upon a properly maintained saw blade and a rate of feed suited to the equipment. An excessive rate of feed for the condition of the blade accounts for most miscuts on vertical band resaws. Resaw blades averaging only $\frac{1}{16}$ inch in thickness can be overcrowded easily in heavy cuts.

If resawing is to be more than a splitting operation, the resawyer must know lumber values and cut for maximum grade. In order to obtain the highest values, the resawyer should be able to see each piece for its full length as it comes to the resaw. Normally the line-up man rather than the resawyer has the best view of the lumber before it enters the resaw. Recently, a resaw that can be set by remote control has been placed on the market. Using remote control, the resawyer may stand in the most favorable position to view the lumber and set for the cut as readily as though he were standing a foot from the resaw.

Pony resaws. Pony resaws are the most expensive of the four types but offer two advantages. First, pony resaws handle larger cants than vertical or horizontal band resaws. Second, they are well adapted to cutting cants of variable quality that could not be cut effectively on a gang. A pony resaw will increase the productive capacity of a mill considerably, and may increase the quality of output more than any other type of resaw.

Pony resaws are similar to head saws except that they saw cants rather than logs. Pony resaws in Class A fir mills are generally 6- or 7-foot double-cutting band mills. A short, lightweight, fast carriage is used, for the pony saw must cut faster than the head saw in order to justify its installation.

A pony resaw permits close attention to quality. The grade-conscious resawyer can see all sides of the cant and can turn the cant quickly as many times as necessary to recover the highest values. The pony resaw is well suited for the recovery of vertical or flat-grained clears from cants that contain common. This type of resaw is also a satisfactory machine for the recovery of high-quality lumber from cants containing considerable defect. If the recovery of high-quality material from defective logs is attempted on the head saw, the mill's production may be lowered too seriously.

Reripping

Re-edgers are used to salvage stock items from mismanufactured pieces, and to raise lumber values, especially by separating a clear edge from a common edge, in one-inch stock.

Green Chain Sorting

Sorting on the green chain represents an approximate grade separation to facilitate subsequent handling of the lumber. As a rule, all clear grades are piled together. This separates clears from commons before seasoning so each can be kiln dried on schedules that will produce properly dried stock with the least falldown in grade.

Green chain sorting is directed by an experienced grader for two reasons. First, some items may be sold as rough green and require grading on the green chain. Second, while marking lumber for pulling, an experienced grader will detect many pieces that can be reworked to increase values.

Seasoning

Many Class A fir mills kiln dry approximately 80 percent of their output—a fundamental step in product improvement. The 80 percent usually includes all items except timbers, certain export items, such as heavy Clears, and No. 3 and 4 Common.

Although most fir mills possess modern dry kilns, equipped to dry on any schedule, the general level of drying practice is lower than that employed by hardwood and ponderosa pine mills. Major emphasis is placed on the volume dried, rather than on quality of drying. This emphasis may be due to limited kiln capacity or to the economics of drying, but improvements in seasoning are needed. For example, kiln-dried, one-inch clears should have an average moisture content of 10 percent, but 90 percent of a shipment may have a moisture concent of 12 percent, and 10 percent of a shipment may have a moisture content of 15 percent. Although this does not represent close quality control, it is more exacting than the usual attention given to kiln-dried stock by shippers, retail dealers and users. Greater care in drying and subsequent handling is required in order to guarantee customer satisfaction.

Dry Sorting

The segregation of grades after drying can be somewhat closer than in green sorting, for seasoning defects will be apparent, but cannot be exact because the stock is still rough. Therefore, it is not possible to select rough, dry stock for a particular planing-mill order and be cer-

tain that the stock selected will make the grades specified on the order.

This problem has led some Class A fir mills to adopt a practice of "blanking" dry lumber. Rough dry lumber is surfaced lightly on two sides to reveal the characteristics of the stock, segregated accurately by grades, and then placed in storage to await orders. The "blanked" thickness usually is $\frac{1}{16}$ to $\frac{1}{8}$ inch heavier than the required finished size, i.e. one-inch stock is blanked to $1\frac{3}{16}$ or $\frac{7}{8}$ inch to permit a finished thickness of $\frac{3}{4}$ or $\frac{25}{32}$ inch. "Blanking" involves extra handling and additional planing-mill costs but reduces the accumulation of rejects in the planing mill. Rejected pieces of slow-moving items are expensive to hold or to rerun to some other pattern.

Quality control in the planing department of many Class A fir mills could be improved by adopting some suggestions of Cahal,[3] on the dry sorting chain.

Planing

Class A fir mills usually are fortunate to have a variety of planing mill equipment, as well as more than one piece of resawing equipment. This means that these mills can run items in machines that are well designed for the particular type of work. No detailed discussion of planers will be included here, other than to refer to Koch's discussion of the quality of surfacing.[4]

Such accessory equipment as an automatic feed table and a double-end trimmer located ahead of the planer assures well butted ends as the pieces flow through the planer and largely eliminates the losses due to "sniped" ends.

Manufacturing practices that improve quality in the planing mill include turning flat-grain flooring strips so the sap side will be the finished face. The practice of easing the edges of dimension lumber in the planing operation is one product improvement that lumber handlers, distributors, and users have approved. Although the practice of double-end trimming lumber to exact length improves its appearance, facilitates car loading, and saves labor on the job, (as in the case of studding), it is opposed by many lumber distributors and contractors.

A frequently noted difficulty that reduces recovery value in the planing mill concerns trimming behind the planer. The fast trim saws now available should enable a trimmerman to do all of the retrimming required for maximum grade recovery if he is allowed to concentrate on trimming. The actual pulling may be done mechanically in order to eliminate the need for an extra man.

The addition of end-matching equipment to a planing mill offers several advantages but relatively few fir mills have installed this equipment. End matchers permit the mill to market relatively high-quality shorts, produced from retrimming long lengths of lower grade, particularly for flooring. Thus, end-matched flooring of B & Btr quality can be produced from D or E grades. At present, the price spread between short, end-matched flooring and long lengths of comparable grade is too great to stimulate interest in end-matchers. However, this price spread should decrease with increasing use of end-matched, softwood flooring. Furthermore, once a mill has end-matching equipment it may consider up-grading items, such as drop siding and sheathing, by cutting out defects. The short lengths produced can be marketed in the same way as end-matched flooring.

Car Loading

Quality control in manufacture should extend through the final handling by the manufacturer, namely car loading. A few Class A fir mills take ample precautions to assure that their lumber will be clean and dry when it reaches the buyer. Furthermore, these mills take care to stack the lumber to facilitate unloading. A recent compilation of buyers' comments regarding western mill service reveals that poor car loading is one of the most common causes of customer dissatisfaction.

General Considerations in Manufacture

Log Barking

Class A fir mills are giving serious consideration to the matter of barking sawlogs before they enter the mill although only one mill has adopted the practice. Many sawmill operators are weighing the performance of barkers under test, or in use at pulp mills.

[3] Cahal, R. R. 1948. Sawing Practices That Pay. 107 pp. Southern Pine Inspection Bureau. New Orleans, La.

[4] Koch, Peter. 1948. Plane Talk for Better Lumber. Wood 3(10):26; (11):34, illus.

The advantages claimed for barking sawlogs include: (1) greater cleanliness in the mill and a reduction of lost time due to bark catching in live rolls or transfer chains; (2) easier inspection of the log by the head sawyer, and of slabs by edegrmen, resawyers and trimmerman; (3) improved opportunities to utilize slabs, edgings and trimmings for pulp chips or other by-products due to the absence of bark. These advantages add up to increased production, reduced losses, and higher grade recovery. They appear certain to lead to barking installations at many large fir mills within the next few years.

Quality Versus Quantity Production

All sawmills are production plants striving to maintain a certain quantity of output; most Class A fir mills have found that quality is equally important. However, quantity of output receives more emphasis. For example, the mill crew is aware each day of how much log scale was cut and competition between a night crew and a day crew may be fostered by posting production figures for each shift.

It might be asked, "How many mill workers know the grade recovery or lumber value for each day or week?" For example, the head sawyer has a ready yardstick of quantity production in the daily deck scale of logs, but he seldom has an accurate measure of quality production.

The managers of two fir mills no longer keep a deck scale. They consider that a deck scale is not only unnecessary but that it places undue emphasis on quantity at the expense of quality. Although lumber recovery values will vary with log supply, a daily or weekly summary of recovery values would stimulate interest in the importance of quality.

Maintenance of Employee Morale

In addition to stressing the importance of quality production, mill managers should strive to maintain good morale among employees. Even experienced and capable employees fail to do their best work if management shows little interest in their welfare. Mill managers can reveal their genuine interest in quality of output not only by instructions and reports of results, but by making improvements that will facilitate quality production.

Good mill lighting is one example of an improvement that proves management's interest in quality production and in better all around working conditions. Benson and Meador,[5] list the following benefits of good mill lighting:

1. Greater accuracy is obtained in sawing, edging and trimming.
2. Production is materially increased since eye fatigue is reduced and time for seeing is also reduced.
3. Mill cleaning is facilitated and the tendency of employees to be careless and indifferent to their surroundings is decreased.
4. Fire insurance rates are reduced.
5. Employee morale is improved with a consequent reduction in labor turnover.
6. Proper seeing conditions help to prevent accidents and also aid in removing potential causes of accidents.

The first, third, and fifth points are significant in respect to quality control. The provision of walls or doors to cut off cold winds in the planing mill; of heat in such spots as the trimmerman's booth; and of partitions to confine machine noises should have a beneficial effect on quality and could lead to higher profit margins in the long run. Such improvements as these would reduce labor turnover and consequently the loss of quality attributable to inexperienced or new employees.

Product Improvement

A few Class A fir mills give major attention to product improvement, serving as leaders for the industry, but in general, the lumber industry has sorely neglected this important phase of quality control. It is necessary to spend time and money to develop improvements in products. It is equally necessary to create consumer demand for these improved products through a sales promotional program. The lumber industry devotes only a fraction of the time and money that competing manufacturers spend on these important phases of quality control. While progressive lumber manufacturers may spend one-half cent per sales dollar for the above purposes, a manufacturer of insulating board

[5] Benson, Donald and Meador, Dean. 1949. Sawmill Lighting Survey. Timberman 50(6):54–57, illus.

or plaster board may spend as much as 10 cents per sales dollar on development work and sales promotion.

The Weyerhaeuser Timber Company initiated the most auspicious product improvement in lumber items with its 4-Square program in the 1930's. A nation-wide promotional effort was launched to create consumer demand for this carefully manufactured lumber. The chief obstacle to the expansion of this program was the unwillingness of buyers to pay a higher price for this better-manufactured lumber. Even the largest manufacturer of west coast woods accounted for such a small percentage of the regional production that its efforts alone were slow to take effect. The wartime situation interrupted the 4-Square program to such an extent that it still is difficult to judge its ultimate effect on the industry.

The West Coast Lumbermen's Association, which derives a large share of its income from the Class A fir mills, is doing an increasingly good job of trade promotion with funds available. However, this effort, combined with those of other manufacturer's associations and those of a relative few individual mills, is not enough in the face of promotional programs for competing materials.

Research and development work on product improvement and new products for the lumber industry is expanding slowly. Agencies such as the U. S. Forest Products Laboratory at Madison, the Oregon Forest Products Laboratory, the Western Pine Laboratory and others are ready to assist the efforts of individual mills with studies on drying, machining, gluing and testing. Equipment manufacturers contribute a fair share to product improvement with machines of better design and improved performance. But, in the final analysis, it is up to the mill itself to take a sustained interest in product improvement, to be alert to opportunities, and to be willing to invest funds and time in putting an improvement on a paying basis. Too many mills have a limited or uncertain future and adopt the attitude, "Let Joe do it."

One hope for improvement lies in the field of specialty manufacture. Many Class A fir mills have undertaken or contemplate the manufacture of specialty products such as insulating board, hardboard, plywood, doors, furniture or furniture stock. Upon entering these fields, the mills find that more rigid quality control and more vigorous merchandising are required. Once the mills have learned this lesson, they are apt to take a more enlightened view of quality control in lumber manufacture.

Furthermore, an increasing number of specialty products are produced from slabwood, bark, shavings or other sawmill surpluses that bring small or no financial returns to the mills. Higher-valued uses of these materials eventually will provide greater profit from each M board feet of logs and permit enterprising lumber manufacturers to further improve their processing and utilization.

Discussion

Mr. E. W. Neils (J. Neils Lumber Co.): Are the barkers now in operation hydraulic or mechanical?

Mr. Grantham: The one now in operation is a hydraulic barker, but at least one mechanical barker is under test.

Mr. A. I. Stuart (Industrial Engineer, Portland): Will you explain the terminology used? Why associate lumber yield with quality control?

Mr. Grantham: I have used the term quality control as applied to lumber manufacture in a very broad sense — to obtain the maximum value from each log cut. Maximum value recovery requires a good quantity yield as well as obtaining the highest grades or quality. At times quality is sacrificed for quantity production but often attention to quality will mean higher quantity recovery, also as in the case of cutting thin slabs, resawing maintaining good saw alignment, etc.

Mr. L. A. Nelson (The Timberman): Mills may cut for quality or for quantity. A mill should cut as rapidly as possible consistent with quality recovery and do it with a minimum of waste.

Mr. R. Schliewe (Weyerhaeuser Timber Company): In analyzing the performance of our barker we found that hydraulic barking increases the lumber yield. Our barker has an oscillating nozzle and the log is moved on trunions.

Mr. C. Y. Robson (Bloedel, Stewart & Welch, Ltd.): Our company has developed and is using successfully a ring type hydraulic log barker. We have two installations, one of 36-in. diameter for small logs and one of 60-in. diameter for larger logs. The logs pass through a drum-like housing with rotating nozzles in sealed rings, bringing water pressures of up to 1250 psi. against the bark on the log traveling through. Our pulp mill is located half a mile from our Port Alberni sawmill, and the debarked slabs go through the normal chipping and screening process direct to the pulp mill. The debarking process has: (1) Greatly increased chip recovery from wood waste; (2) Improved sawmill efficiency through giving a clean log to work on in the sawmill manufacturing process. Direct benefits here include better opportunity for analysis of log defects by the sawyer, and consequent ability to make the most of grades; and longer saw life, with reduced lost time from saw changes caused by striking gravel or foreign matter imbedded in the bark.

Mr. Grantham: Do you know of any mills that have abolished the deck scale for logs and rely on some other measure of production that will reflect quality recovery?

Mr. Nelson: Some mills rely on the Woods Scale rather than a deck scale, but most mills must keep a deck scale. Many mills summarize grade recovery monthly. It is time consuming and difficult to summarize grade recovery at shorter intervals. There should be more attention to grading throughout the mill. Too few millworkers have a knowledge of grading which is prerequisite to cutting for quality.

Mr. C. M. Brink (Pacific Manufacturing Company): No mention has been made of warp or flatness to be expected in Douglas fir shop lumber. How is this considered in grading?

Mr. Nelson: Although not mentioned specifically in the grading rules, it is understood that the cuttings must lie flat.

FOREST PRODUCTS RESEARCH SOCIETY

Techniques in Hardwood Plywood Quality Control

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and

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Statistical quality control methods which have been used successfully in many industries have been adapted to the problems of quality control in the manufacture of hardwood plywood. The proper use of the control chart technique provides the production manager with a useful tool for improving plywood quality and increasing the uniformity of the product. The use of statistical quality control methods can also assist in the reduction in waste and degrade.

Introduction

INTEREST in improving the quality of hardwood plywood has been increasing during recent years. Evidence of the fact is the development during the last three years of an active quality control program by the Southern Plywood Manufacturers Association.[1] This program includes a laboratory plywood testing program, sponsorship of a gluing clinic and operation of an industry wide grading school for the training of plywood graders. Further indications of an increased interest in quality on the part of hardwood plywood manufacturers is the action of the Hardwood Plywood Institute and the Southern Plywood Manufacturers Association in promoting improvement in the grade and glue line requirements of the hardwood commercial standard in recent revisions.

This interest in improving the quality of the final product has quite naturally led to an active interest on the part of manufacturers in improving the manufacturing process and in control over the quality of the materials entering into it. It has been well established that quality control in plywood manufacture cannot be accomplished simply through inspection of the final product but must be devoted to control of the entire production operation. The quality control procedure normally includes the two functions of testing and inspection. The testing function is a laboratory job which will include testing the quality of the glue bond and may include tests for veneer moisture content, glue quality and other similar items. The inspection function involves examining materials and processes to insure that they conform to established quality standards. At the green end, inspection would include examination of veneer for smoothness of cut and accuracy and uniformity of thickness. The drying operation would be checked for proper and uniform veneer moisture content. Green and dry clipping operations would be inspected to insure that dimensions were correct and that veneer was cut square. Taping and splicing operations must be inspected for quality of joints. In the glue room, inspection would cover glue mix and spread, lay up, press operation, time-temperature curing cycles and conditioning and hot stacking. The finishing inspection will include checking the finished panel for grade, size and thickness, squareness and sanding.

It is obviously uneconomic and unnecessary to make all of these inspections by quality control personnel continuously. Inspection, therefore, must be essentially a sampling process and it is always a quality control problem to determine how intensive this sampling should be. If it is too intensive, inspection costs will be excessive. If it is too cursory, control will not be maintained.

Advent of Statistical Methods

The search for methods which could be used to produce hardwood plywood has led in several instances to the adaptation to plywood manufacture, of statistical quality control methods which have proved valuable over a period of years to quality control engineers in other

[1] Bethel, J. S. Quality control in producing hardwood plywood. Southern Lumberman, April 1, 1950.

industries.[2] Preliminary exploration suggests that many of these methods are useful tools for the improvement of average quality and uniformity in quality. In addition these quality control tools give high promise of pointing the way to reduction in costs through savings in labor and materials. They provide methods of determining the proper level of inspection required to control quality without conducting expensive over-inspection.

It is not the purpose of this paper to cover all of the elements of hardwood plywood manufacture which are susceptible to statistical quality control nor to attempt to include all of the statistical treatments which can be used in such control. There are ample data published covering adaptations of the various quality control techniques to a wide variety of production problems which are available to plywood plant management interested in the use of this tool.[2] [3] [4] It is the object of this paper to examine the application of some statistical quality control techniques to a few specific problems as an indication of the way in which the method can be used.

Statistical Method in Controlling Veneer Moisture Content

One of the critical problems continuously faced by plywood manufacturers is that of maintaining adequate control over the moisture content of the veneer going into the product. The moisture content selected as the target of the drying process will depend upon the equilibrium moisture content conditions in the plant, the E. M. C. conditions expected in subsequent storage and use, the veneer moisture content requirements of the adhesive being used and on other factors. The range of moisture contents above and below the target moisture content which can be allowed will depend upon such factors as the seriousness of warp as a defect in the final panel, how critical are the working properties of the adhesive, what degree of moisture resistance is required of the finished panel and other similar items. For any veneer drying operation there are limits to the variation in moisture content which can be permitted if production is to be efficient, if the number of rejects kept within reasonable limits and if the final product is to meet the appropriate specification requirements. Regardless of whether these limits are precisely known or measured they nevertheless exist.

When it is desired to exercise control over the veneer drying process the Shewhart[5] control chart method of statistical quality control is a useful management tool. The use of the control chart will not in itself result in control of the quality of the veneer drying operation but it will give the production manager a basis for determining whether his drying operation is under control, and if not it will provide him with clues as to the actions which can be taken to bring about control. Further it will tell him whether the process is sufficiently accurate to provide him with an acceptable product even when statistical control is present. Ferris[2] has described an application of the Shewhart control chart to veneer drying operations. Fig. 1 illus-

[2] Ferris, D. W. Statistical controls for dimension materials. Wood, August 1947.

[3] Ferris, D. W. Quality control formulas, tables, and processes in manufacturing veneer. National Hardwood Magazine, September 1947.

[4] Grant, E. L. 1946. Statistical quality control. McGraw–Hill, New York.

[5] Rietz, R. C. 1947. Method for controlling the moisture content of wood going into furniture production. U. S. Forest Products Laboratory Report R 1685.

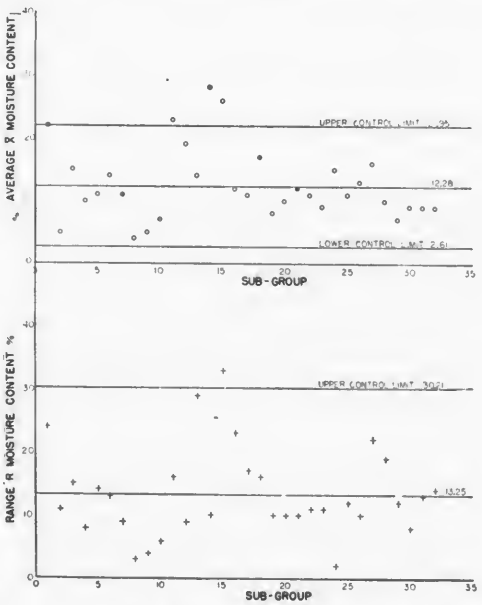


Fig. 1.—$\bar{X}$ and R charts for red gum veneer $\frac{1}{10}$-inch thick dried in commercial veneer drier.

trates a portion of a control chart prepared according to Grant[4] for average $\bar{X}$ and Range R for a veneer drying operation on 1/10-in. red gum veneer. The $\bar{X}$ chart shows the hourly moisture content values plotted. Each sample consists of the average of four moisture content determinations taken at random. Moisture content was obtained by the oven method. The center horizontal line represents the average for the data and the remaining two horizontal lines represent upper and lower control limits of three standard deviations.

At the time these charts were prepared the manufacturer was attempting to obtain a ten percent moisture content. A urea-resin glue was being used whose veneer moisture tolerance limits according to the glue manufacturer was between 5 percent and 15 percent. Examination of this control chart reveals several interesting facts concerning the veneer drying process. The points falling outside of the control limits suggest that the process is out of control[6] and that there are assignable causes for the excess variation in the average and range that can be determined and corrected. It will also be noted that the average $\bar{\bar{X}}$ of the $\bar{X}$'s has a value of 12.28 percent moisture content instead of the 10 percent target moisture content. Further, an examination of the upper and lower control limits on the $\bar{X}$ chart reveals that they are far outside the 5 percent and 15 percent requirements of the glue manufacturer's specification.

Application of the Charted Data

There are several possible courses of action suggested by this control chart. The assignable causes for the excess variation indicated by the points lying beyond the control limits may be searched for and identified and corrective action taken to bring the process into control. The operation of the drier may be altered slightly in the direction of slower average speed or higher average temperature to bring the $\bar{\bar{X}}$ closer to 10 percent moisture content. While these two actions should improve the drying process and bring it into control they cannot reasonably be expected to bring about a change in the position of the control limits such that they would fall within the specification limits of 5 percent and 15 percent. Improvement in that direction would likely to be obtained only by making some fundamental changes in the drying process which would make it more accurate. In the case in question it was felt necessary to attempt to improve the process in all three directions. That is to bring it into control, move the $\bar{\bar{X}}$ nearer to 10 and improve the basic process to bring the control limits within the specification limits.

A study of the drying process revealed several major sources of variation. The drier operators were paying little attention to the established drying schedules. They were operating the drier from the dry end by checking the moisture content of the veneer with a moisture meter and then making an adjustment in the drier speed or temperature on the basis of this check. In addition, the steam pressure being maintained was quite variable and the drier operators were frequently trying to control drier temperature at a point above that which the available steam pressure could consistently provide. As a result there was no uniformity in drier operation and often changes were made so frequently that it was impossible to determine without tagging it how long a given piece of veneer was in the drier or on what temperature schedule it was dried. It was also observed that the thickness of the veneer varied considerably around the nominal 1/10-in. thickness thus resulting in a population of veneers with a wide range of drying rates based upon thickness. Heartwood was not being dried separately from the sapwood, although red gum heartwood and sapwood have quite different drying rates.

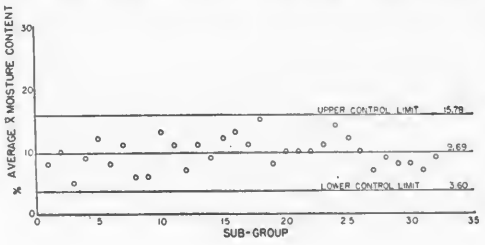
The following action was taken:

1. Drying schedules were revised by means of laboratory experiments and the drier operators were required to adhere to them.

[6] Actually a valid determination that the process was out of control would require that the control limits be based upon more than 32 sub-groups, however, the principle is correct and as the system is extended to include more sub-groups confidence in the control limits can be increased. In addition the validity of the initial control limits based upon data which exhibits apparent lack of control may also be questioned. In practice new control limits would be calculated as additional data became available.

2. An effort was directed at the maintenance of more uniform steam pressure and drier operators were instructed to set temperature controls at a point where the temperatures could be maintained at a constant.
3. Action was taken at the green end to improve the uniformity of veneer thickness.
4. Heartwood and sapwood were separated at the green end and dried to separate drying schedules.

Fig. 2 illustrates a portion of a control chart representing drying obtained after the actions listed above had been taken. It will be noted that the process exhibits statistical control and



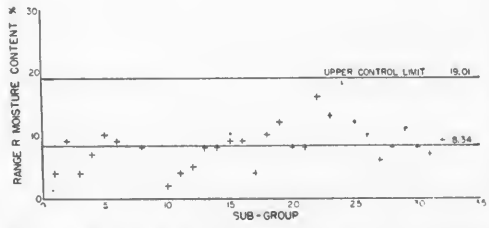
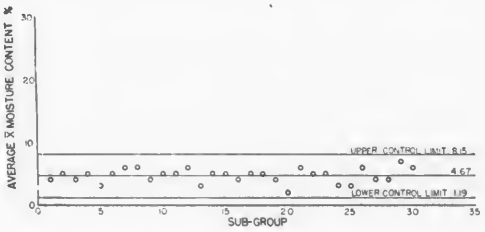


Fig. 2.—$\overline{X}$ and R charts for red gum veneer $\frac{1}{8}$-inch thick dried in commercial veneer drier.

the $\overline{X}$ of 9.6 percent is very close to the target of 10 percent, however, the control limits on the $\overline{X}$ chart of 15.78 percent and 3.60 percent are still somewhat outside of the 5 percent to 15 percent specified by the glue manufacturer. If it were desired to again take action to improve the control limits another refinement in the drying process would be indicated. It was decided in this instance not to take further action immediately for several reasons. First, gluing rejections which had previously been high and for which non-uniform veneer drying was thought to be responsible, had virtually been eliminated. The time elapsed since the change in drying process was not felt to have been sufficient for the full benefits of this change to have accrued and have been reflected in the control chart. To have further refined the drying process would have meant making major changes in the drying equipment. The advantages to be gained by this additional refinement in drying operation could not justify the cost. In fact control charts resulting from data subsequently collected confirmed the wisdom of this decision when control limits fell within specification limits.

Fig. 3 illustrates a control chart obtained for a drying operation on $\frac{1}{8}$-in. red gum veneer



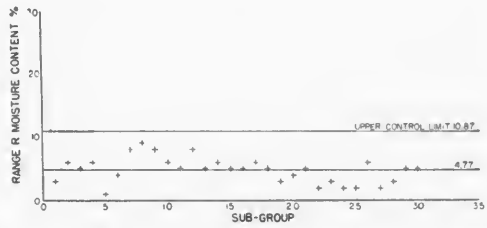


Fig. 3.—$\overline{X}$ and R charts for red gum veneer $\frac{1}{8}$-inch thick dried in commercial veneer drier.

which was being used in the production of waterproof plywood bonded with a phenol-formaldehyde resin adhesive. The veneer moisture content tolerances of the glue as specified by the manufacturer were between 4 percent and 8 percent. This process indicates statistical control. The glue joints being obtained were satisfactory and panel warpage was not excessive. It will be noted that the $\overline{X}$ was substantially below the specification midpoint of 6 percent and that the control limits about $\overline{X}$ exceeded those specified by the glue supplier.

It was established however, that if the target moisture content was raised to 6 percent the spread between the control limits would be increased and that gluing trouble would be experienced. To have maintained a suitable range around a target moisture content of 6 percent would have required the major changes in process noted in the previous paragraph. Inasmuch as the panels being produced were considered satisfactory, the additional costs involved in further refinement of the process could not be justified.

This illustrates a problem that frequently comes up when quality control charts are being used. The process may be brought into statistical control but the control limits may exceed the specification limits. When this happens a decision must be made to either refine the process to bring the control limits within the specification limits or to re-examine the specification limits with the object of determining whether they should be changed. In this instance, since the product being produced was satisfactory it was decided that the specification limits were too restrictive and should be modified.

These examples, were presented to indicate the way in which the Shewhart quality control chart can be used in controlling an operation in the manufacture of hardwood plywood. It should be again emphasized that use of this type of chart does not guarantee quality control. It serves as a tool which the production supervisor can use to determine whether his operation is in control, and whether the control is being accomplished within acceptable limits. It can furnish him with a guide to corrective action if it is indicated. It may indicate that excessive variation is due to assignable causes which can be corrected by closer supervision of machine operators and foremen or by adjustment or repair of a machine. On the other hand it may indicate that the material being processed is itself so variable that the operation cannot be controlled within proper limits, or that the equipment used to perform the operation may not be basically accurate enough to satisfy specification requirements. When the latter two cases prove to be true no amount of closer supervision or disciplinary action applied to employees is likely to correct the difficulty. Either the specification limits must be changed to accommodate the production operation, the basic process must itself be improved or a 100 percent inspection must be set up to reject unsatisfactory material.

All of the preceding discussion has been based upon the assumption that inspection processes are themselves accurate. It is obvious that there is a normal variation present in the inspection process just as in the manufacturing process. This is provided for in the statistical techniques used. Mistakes made in the inspection, however, may result in charts which indicate faults in the production process when they are not present. And even more insidiously they may result in charts which indicate a satisfactory process when in fact it does not exist. It should be axiomatic that before any action is taken on indications from a control chart, the inspection operation should itself be checked to insure that the fault does not lie there.

Controlling Other Operations

There are many operations in the production of hardwood plywood other than the drying operation to which the Shewhart control chart for average and range can be admirably adapted. A few examples are:

Controlling the thickness of veneer, control of dimensions in clipping, control of glue spread, control of glue joint quality, control of panel dimensions and others.

Not all of the possible analyses of the control chart have been discussed. In addition to the indication of lack of control resulting from the presence of points outside the control limits, lack of control may be suggested by a run of points within control limits but entirely on one side of the line of $\bar{X}$ or $\bar{R}$. These are refinements in the use of the control charts which increase their use and which can be developed further after the system has been put into use and experience with it has been obtained.

One service which the properly used control chart can perform for the production supervisor is to tell him when a process or operation is in control and should be let alone. The observation was previously made that one of the assignable causes for lack of control in the drying operation was the tendency of the operator to change the speed and temperature setting on the drier frequently. This is a common fault of operators of other machines such as lathes, glue

spreaders, sanders, saws, etc. Every production manager is familiar with the operator who can't let his machine alone. He has to change its set up constantly. It is rare when a properly built and maintained machine being used for the purpose for which it was designed has to have constant adjustment. Most frequently such continuous tinkering is actually contributing to greater variation in quality rather than less. The control chart will indicate when a process is in control and can be used by supervisors to eliminate unnecessary manipulation of machine set-ups.

Another type of quality control chart which has some application to plywood manufacture is the control chart for attributes. An example of such a chart is shown in Fig. 4. This type of chart may be used to control processes where the inspection is not for a measurement but for the purpose of putting the item inspected in one of two classes—acceptable and rejectable. These charts are frequently called the chart for fraction defective. Ferris[2] has described the use of the chart for fraction defective to control the dimension and grade of hardwood dimension stock. The chart illustrated in Fig. 4 is one applicable to the control of thickness of finished plywood panels. Because of the nature of the assembly in which the plywood was being used, control of the thickness was extremely important. The plywood was required to conform to a thickness tolerance of plus or minus a sixty fourth of an inch. Since the panel was of the overlay type there was no opportunity to control the thickness in a sanding operation. It had to be manufactured to the correct thickness out of the press. Panels were checked for thickness with a "go and no go" gauge or a dial-snap gauge and recorded as being either acceptable or rejectable.

In preparing the chart the 20 sub-groups were used as a basis for establishing the original control limits. It will be noted that the control limits for this chart are irregular in contrast with the straight lines shown in the X and R charts. This is because the sub-groups represent a day's production and accordingly the sub-group sizes are variable. If the sub-group size were a constant, the control limits would be straight lines. If it is desirable for purposes of simplicity to have straight control limit lines even when it is necessary for inspection reasons to have variable sized sub-groups there are acceptable techniques[4] for calculating approximate straight line control limits although such limits are not as precise as are those determined as in this example. The points falling outside the upper control limit indicate the possibility

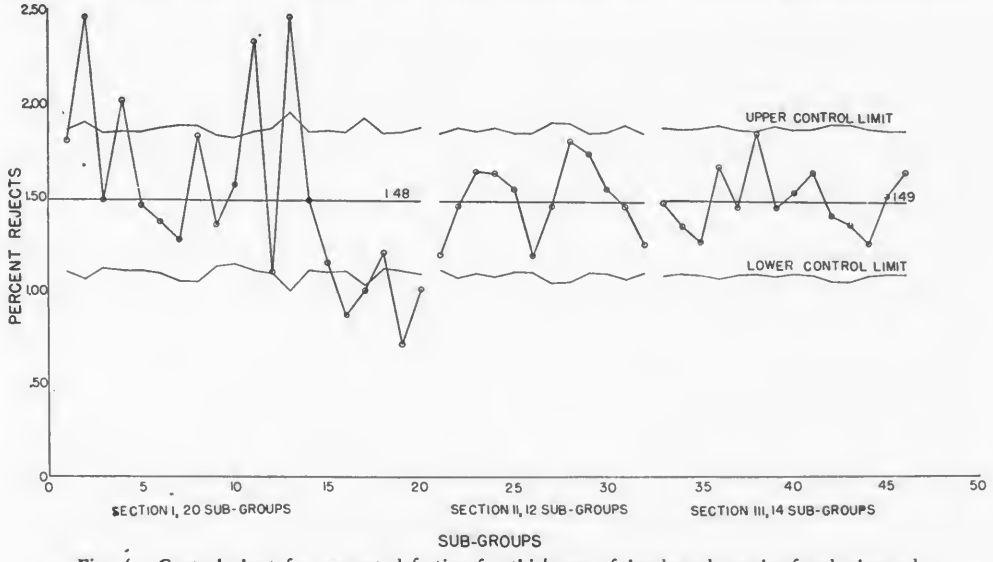


Fig. 4.—Control chart for percent defective for thickness of hardwood overlay-faced plywood.

of assignable causes for panels which were too thick or too thin. Those falling outside the lower control limit suggest improper inspection techniques. The out of control points above the upper limit could of course also be due to inspection faults. The action indicated by this chart is to complete examination of the process for causes of excess variation and a study of inspection procedures for faulty equipment and techniques. In this instance it was found that two causes for excessive variation in thickness were too much variation in veneer thickness and the use of the same pressure in hot pressing woods of different densities. Examination of the inspection processes revealed careless use of gauges, and a worn "go and no go" gauge which was allowing excessively thick panels to pass.

The portion of the chart for the second group of 12 sub-groups shows the process in control after corrective action was taken. The same control limits are used for evaluating the process. The final fourteen sub-groups show a continuation of the process in control. New control limits were calculated from data collected while the process was in control but they are not too different from the original limits. Generally, this type of control chart has fewer applications to plywood operations than does the chart for X and R.

No attempt has been made to cover in detail the techniques of preparing quality control charts. There are ample references available covering these methods and the statistical theory upon which they are based. Methods of utilizing the charts for analysis of a few plywood production operations have been illustrated. There are many additional adaptations that can be made. In addition to furnishing the production supervisor with a measure of his success in controlling quality and with clues to the source of extraneous variation in quality when it exists, the proper use of statistical quality control methods can be expected to contribute to lower costs through reduction in waste and down graded panels. With emphasis by manufacturers on improvement in the quality of hardwood plywood, statistical quality control techniques should prove increasingly useful tools.

Discussion

Mr. Jack B. Cunningham (Woodwelding, Inc.): During World War II considerable trouble was encountered in using hardwood plywood due to failures in bonding particularly when Tego film glue was used. Do you feel that statistical quality controls could have avoided some of this trouble?

Mr. Carter: War time wood inspection procedures and plywood manufacturing inspection were sadly lacking in statistical quality control. As a result tolerances in inspection were variable between plants and between inspectors. Statistical control could have established the limits for manufacturing and inspection. When out of control or near the border line inspection could look for assignable causes rather than merely rejection.

Veneer to be glued with Tego film should have rather narrow moisture content limits, of around 8 to 12 percent. It is practically impossible to meet this limitation with present veneer drying equipment and drying procedures. Other factors such as thickness of veneers, pressure, press platen uniformity and glue curing operations enter into plywood quality. All of these factors can be subjected to statistical quality control treatment. If such a technique had been used I feel confident that plywood rejections would have been materially reduced.

Mr. C. F. Van Epps (Stromberg-Carlson Company): Perhaps the prime advantage of Tego is that it adds no moisture to two sheets of veneer when bonding them together thus being particularly adaptable for thin veneers and for fancy faces. In fact, it is widely used in two plying fancy faces for this reason. The chief difficulty in handling Tego film arises from something Roy Carter mentioned, the close control of veneer moisture content necessary. If too much moisture is used, excessive flow occurs and a starved joint results. If too little moisture is used, no flow and no penetration occurs. It is best to operate closely within the manufacturers recommendations for moisture content.

Mr. Charles Latimer (Nickey Brothers): It should be pointed out that a process such as veneer drying may or may not exhibit a state of control depending upon the method of sam-

pling. Samples may be taken in such a way that a relatively large range is obtained with consequently wide limits or samples may be taken so that a relatively small range is obtained with narrow limits which may show a lack of control. The important thing is to use the same method each time a sample is taken.

Mr. Carter: That is true. The samples should be taken in such a way so as to maintain the quality desired in the product whether low or high. Normally wide limits give quality control for a lower quality product. Narrow limits usually results in higher quality end products.

Mr. Van Epps: Proper quality control presupposes the proper specifications as a guide for manufacture and for the evaluation of a finished product. Proper specification simply means that the idea of the designer and the engineer must be translated in readable terms to the production people who fabricate the part, and to the inspection people who pass on the quality of the item. Usually this is accomplished by sample. Where specifications are used a distinct attempt should be made to refer to published data such as the Commercial Standard Specifications, the Mahogany Book, governmental specifications, or something similar accepted as standard terminology.

Many points of quality control cannot be stated specifically in a specification. For example, Comb Grain Oak, without a sample, is difficult to define within specification limits. The brilliance or depth of color in a finish cannot be defined without a sample nor can an actual swirl or crotch figure be defined without a sample.

It is true also that many of our quality control points show only after the cabinet is completed. For example, surface defects may show only after finishing, a specific case being the penetration of synthetic resin glue through the face veneer, detectable only by ultra-violet light in the white, but very prominent after staining and completion of the finish.

Mr. Carter: The problems you mention are universal in figured face veneered panels. Undoubtedly more investigation is needed to establish assignable controllable causes that can be put into production.

Dr. Bethel: Referring to Mr. Cunningham's question, the control of quality in a gluing operation, assuming that the glue itself is good, is largely a problem of controlling the operating variables which influence glue line quality such as temperature of veneer, moisture content of veneer, pressing temperature, time under pressure, pressure, etc. These variables are susceptible to treatment under statistical quality control methods. Also the results of performance tests on the glue line such as the boil and shear test can be analyzed through the use of the control chart. Such applications should have value in controlling glue line quality.

The question of specification clarity is an important one as far as statistical quality control is concerned. Some specification requirements for plywood are unrealistic productionwise and frequently they are also unnecessary. One important function which statistical quality control techniques can frequently perform is to demonstrate factually the faults in specifications and provide a basis for their correction. Such specification requirements as the grades of fancy faces mentioned by Mr. Van Epps are difficult to handle from a statistical standpoint and certainly X and R charts which require measurements as a basis are probably not applicable. A chart for fraction defective based upon inspectors daily reports may be of value both to inspection and production personnel in dealing with problems of grade, finishing, etc.

Grant states that: "a control chart may be thought of as a statistical test to determine whether the variation from sub-group to subgroup is consistent with the variation within the sub-groups". "If it is desired to determine whether or not a group of measurements is statistically homogeneous (i.e. whether they appear to come from a constant system of chance causes), sub-groups should be chosen in a way that appears likely to give the maximum chance for the measurements in each sub-group to be alike and the maximum chance for the subgroups to differ one from the other". It is certainly true that sub-groups should be selected in the same manner with each sample.

Mr. R. C. Fraunberger (Philco Corporation): Quality is important to the wood industries. The slogan, "Famous for Quality the World Over" is a goal that should also be adopted by many other woodworking concerns.

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Quality Control in Furniture Production

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A survey of quality control in Southeastern United States furniture plants showed that there was considerable variation in practices and room for improvement. Proper organization for quality control, written standards of quality, and effective inspection of raw materials, parts and finished products should improve the control of quality in many plants. The relatively new technique of statistical quality control appears to be an outstanding development for consistently maintaining conformance to the quality standards of a furniture company.

Introduction

THE purpose of this paper is to summarize the existing practices which control the quality of furniture being produced by factories in southeastern United States and to list methods for improving quality control. If furniture produced by a certain factory starts to get poorer in quality, customers will refuse to buy the product. If the furniture starts to get better in quality than planned, the factory cost may go up to the point where the plant loses money. This paper will be limited to discussion of controlling the quality of wood furniture and does not cover upholstered products.

Defining certain terms may help to clarify the subject covered in this paper. *Quality* as used herein does not signify good, bad, high priced or low priced merchandise. *Quality* is defined as conformance to a set of standards under which furniture is produced. *Quality Control* means the procedures carried out by a furniture factory in order to produce products that conform to the set of standards applicable to that particular factory. *Inspection* is that phase of quality control consisting of examination of raw materials, parts, and finished products to see if they conform to the standards set up and the acceptance or rejection of the items examined.

Statistical Quality Control is the application of statistical and engineering analysis techniques to the control of the quality variables in a production process. The word *statistics* has two different meanings. When used as a plural noun, it refers to any facts stated in terms of numbers. As used in reference to statistical quality control, statistics is a singular noun and is concerned with methods by which useful conclusions can be drawn from numerical data. "Statistics is based in large part on the law of large numbers and the mathematical theory of probability." This paper does not cover the mathematical background or the details of installing statistical quality control in a plant. To help explain the reasons for using this technique, its use is developed in the sections of this paper covering lumber seasoning and machining.

Existing Quality Control Practices in Furniture Plants

In order to determine what procedures are now being used to control quality, questionnaires were sent out in March 1950 to ninety furniture plants randomly selected from the list of members of the Southern Furniture Manufacturers' Association. Replies were received from fifty-three companies covering high-, medium- and low-priced furniture. Fig. 1 shows a copy of the questionnaire used in the survey. This has been filled in with figures which are a summary of the plants who returned the questionnaire.

The summary yields some interesting information. Some plants have a quality control department, others do not. In those plants having a separate department, the quality control head may report to the president, general manager, production manager, or superintendent. Incoming materials are checked by various departments and a few plants do very little inspection

QUALITY CONTROL IN FURNITURE PLANTS

QUESTIONNAIRE

In each question please check the item which most nearly represents the condition in your plant.

1. Quality Control Department: Do You Have - (a) Separate Department 10 ,

One Man in Charge 13 , No Department or Man in Charge 30 .

(b) If you have Quality Control Department, Department or Man Checks All

Incoming Materials 10 , lumber ____, veneer ____, glues ____ } Highly variable

finishing materials ____, other materials ____.

(c) If Quality Control Department or Man Does Not Check All Incoming Materials, materials are not checked 5 , materials checked by

receiving clerk 18 , materials checked by foreman 30 .

(d) To whom does Quality Control Head Report? President to Superintendent.

(e) Please list number of inspectors in each department and check to whom they report:

		REPORT TO				
Department	No.	Quality Control	Production Foreman	Plant Supt.	Manager	Other
Yard	1-10	Highly Variable				
Rough End	1-14		"	"		
Veneer & Plywood	1-8		"	"		
Machine	1-12		"	"		
Sanding	1-10		"	"		
Cabinet	1-9		"	"		
Finishing	1-8		"	"		
Rubbing	1-9		"	"		
Shipping	1-13		"	"		
Receiving	1-14		"	"		
Carving	1		"	"		
Other	1-9		"	"		

2. Total number of production workers in plant 50-2000 .

3. Do you have a quality control laboratory? Yes 5, No 18

4. Who sets quality standards? President ___, Sales Manager ___ Plant Manager ___, Plant Supt. ___, Foreman ___ Purchasing ___ Plant Engineer ___, Designer ___, Do not have any standards ___. Highly Variable

5. Who sets material specifications required to meet quality standards? Highly variable.

6. If you have standards, are they: Written 16 or Oral 37 ?

7. Do you work to definite written tolerances in machining parts such as .18 3/8" plus or minus 1/32"? Yes 15 No 38

8. Do you work to definite tolerances in fitting of parts, such as 1/64" to 3/64" clearance on each side of flush drawer? Yes 13 No 40.

9. For such items as color, veneer figure and appearance of finish, do you have samples on display to guide the workmen? Yes 35 No 18

10. Statistical Quality Control: (a) Do you have this for control of moisture content of lumber? Yes ___ No ___ (Questionable)

Do you have this throughout your operations? Yes ___ No ___

Do you have statistical quality control in any other departments? Yes __ No

Are you planning on installing statistical quality control? Yes ___ No ___

11. What price range furniture do you manufacture? High 11 Medium 32 Low 10

Fig. 1.—Quality control questionnaire.

of incoming materials. In different plants, the number of inspectors varies from a low of one inspector for each forty production workers to a high of one inspector for each twelve production workers. A few plants perform all inspection by production workers and production foremen. A very few plants have a quality control laboratory. Quality standards are either set by the president or a group of top management. Material specifications are set by every division of management. The standards are usually oral rather than written. Some plants work to definite tolerances usually not written, others do not use tolerances. Most plants use samples to guide workmen. There seems to be considerable interest in statistical quality control but evidently many plants do not understand exactly what it is.

Most of the factories included in this report have a high volume of production and employ a majority of semi-skilled workers. A few factories producing high quality furniture in a somewhat limited amount consistently maintain a high standard of quality yet utterly disregard many of the principles enumerated in this report. This is done by having only skilled operators in key positions who have worked with the company so long that the proper quality standards have become a part of their working tools. They produce their work to standard or they do their work over again of their own accord. The products of this type plant may consistently conform to the standards set by management but the cost of maintaining this quality is usually uncontrolled and may be unknown to management.

Conclusions From Analysis of Existing Practices

An analysis of the questionnaires used in this study and the writers' personal knowledge of furniture plants in southeastern United States indicates that there is wide variation in methods used to control quality and that there is room for improvement. It is recognized that each plant has its own peculiar problems that must be individually solved; but there are definite principles of quality control that can be applied to nearly every furniture manufacturing operation. There appears to be a considerable lack of organization for quality control, some weakness in setting quality standards and variation in the quality of furniture produced. The balance of this paper will cover the organization and operations which will tend to produce furniture of uniform quality.

Quality Control Organization in a Furniture Manufacturing Company

Quality control was defined in the introduction as the procedures carried out by a furniture factory in order to produce products that conform to the set of standards applicable to that particular factory. Insuring conformance should be done at a minimum cost. A balance must be struck between the value of quality and the cost of quality. In performing the quality control function properly, individual plants will vary according to the size and internal organization of that particular company. However, certain fundamental principles can be applied to any company. For instance, over a long period of time, uniform quality in the finished product can only be expected if the responsibility for quality control is some one person's primary duty. Unless someone is continuously checking quality, the pressure of production or other forces may gradually change the quality of the product being produced or change the cost of obtaining quality. In other words, there should be a separate quality control department or one man in charge of this work. The chief activity of a quality control department is inspection. The quality control department may include the inspection department or may *be* the inspection department. The inspection department usually performs only the inspection act, while the quality control department may include engineering work to improve quality and other related activities. Sometimes a laboratory for research and control testing may be included within the quality control department.

In order to command the respect of the factory man, the quality control department head should be on a high level of authority comparable with the plant superintendent and chief accountant (2). Although it is advisable to keep inspection control above the level of the production workers and foreman, too high a position of inspection can cause inspection to become excessively strict and costly. Juran (2) states one principle of inspection very well: "The first common supervisor of the operator and the inspector should be at the lowest level of authority that is staffed with executives who reflect the company's policy on the balance between cost of quality and value of quality." In a furniture factory, this level of authority may well be the plant superintendent; although some larger companies have placed this level of authority one step higher with the plant manager.

The best way may be for the inspectors to report directly to a chief inspector who reports to the plant superintendent; but, in the larger companies, the top quality control man would report to the production manager and would act in an advisory capacity to the individual inspectors and plant superintendents.

Establishment of Product Quality Standards and Material Specifications

In order to control properly the quality of goods being produced, definite quality standards should be established. Standards should be expressed in writing or be represented by samples. Oral explanations may be helpful but an inspection department must have definite written or sample standards on which to base acceptance or rejection of items or the quality of product will vary from month to month due to human variables such as temperament and memory. The quality standards should be set by top management. However, several persons or departments usually will have to contribute to the standards. The designer and the sales manager will specify those items which will affect the appearance, performance and sales appeal of the article. The process engineer, who frequently will be the plant superintendent, will specify part sizes and details of construction. New developments in gluing, finishing and other processes require that new standards be developed. According to Trayer (3), quality control in wood processing must be based upon technical facts obtained through research. During the past five years many furniture plants would have saved considerable money chargeable to gluing troubles if they had had the correct technical information.

Certain material specifications are necessary to meet the product quality standards. These material specifications may be set by the plant manager, superintendent, engineer, purchasing agent, designer or sales manager depending upon the type of product and the individual plant organization. When the specifications are put down in writing and are represented by samples, receiving inspection is greatly simplified.

Inspection of Incoming Materials

Approximately fifty percent of a furniture plant's sales volume is represented by raw material purchases. Consequently, the specification, purchasing, inspection and use of these materials is extremely important. Since lumber, veneers, glue and finishing materials are bulky commodities, they are frequently delivered to the department using the material rather than to the supply room. The balance of materials are usually delivered to a receiving clerk in the supply room. The inspection of these materials varies considerably. The receiving clerk in the supply room can do whatever inspection is necessary for the items received there. Since most plants successfully use the yard foreman or his assistant to inspect incoming lumber, this inspector can be left under the control of production. Frequently, the lumber inspector is supervising a lumber stacking crew at the same time as he grades lumber. Lumber inspectors could be put under a chief inspector as far as the actual grading is concerned; but because of the production supervision, lumber inspectors are probably as well if not better placed in the production department. Face veneers are bought by samples but random checks on footage should be made by an inspector to see that the supplier's count is correct. The footage of rotary-cut construction veneers should be checked by count or measurement; the size and moisture content by random selection. Because of the intermittent receipt of shipments, this check is frequently made by the veneer department personnel but a receiving inspector can very well do this work if the plant organization is suitable.

New developments in glues and finishing materials have been and are being put into production in many furniture plants. Consequently, the need for receiving inspection of these materials is becoming more important each year. A number of plants now have laboratories for testing these materials. Those plants with testing laboratories should make random checks on all materials received. Fig. 2 shows a form used by a large furniture company in North Carolina to test receipts of resin glues in tank car lots. The average plant without a laboratory should make random checks on incoming materials with rough plant checks of test panels and occasionally send samples to a testing laboratory for checks on the raw materials. Keeping substandard materials out of production is a fundamental method of maintaining quality control.

Lumber Seasoning

Wood furniture cannot be manufactured to a definite quality standard unless the lumber is seasoned properly. High moisture content boards will eventually shrink and stressed boards may warp. Proper methods of air seasoning, kiln

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APPROVED. _____

GLUE QUALITY CONTROL TESTS

Plant _____ Date of Tests _____ Glue _____

Company _____ Type _____ Batch No. _____

Quantity Received at Plant _____ Date Manufactured _____

Date Shipped _____ Date Received _____

LABORATORY TESTS

A. Glue Formulation: Wheat Flour _____% Water _____% Catalyst _____%

B. Open, Closed Assembly Time _____ minutes

C. Hot, Cold pressed _____ minutes, hours @ _____ p. s. i.

D.

	As Received	Mixed
pH		
Viscosity		
Solids Content		

E.

PLYWOOD SHEAR TESTS

DRY				WET	
Panel a		Panel b		(48 hrs. in Water @ Rm. Temp.)	
1		1		2	2
3		3		4	4
5		5		6	6
7		7		8	8
9		9		10	10

Ave. _____

(First figure represents shear p. s. i.
Second figure represents % wood failure.)

Remarks _____

Tested By _____

Fig. 2.—Form for glue quality control tests.

drying and conditioning lumber are well established by the U. S. Forest Products Laboratory and others. If these methods are followed, good material will be produced; but recent developments have shown how to regulate the quality of drying according to the need of the particular plant. Rietz (4) has conducted experiments for the Forest Products Laboratory which have shown how statistical quality control can check the results of kiln drying and even predict when drying will be out of control.

Statistical quality control is based upon the use of charts which show when an operation is in control or out of control. The Shewart (5) control chart is an essential tool in statistical quality control. Fig. 3 shows a control chart

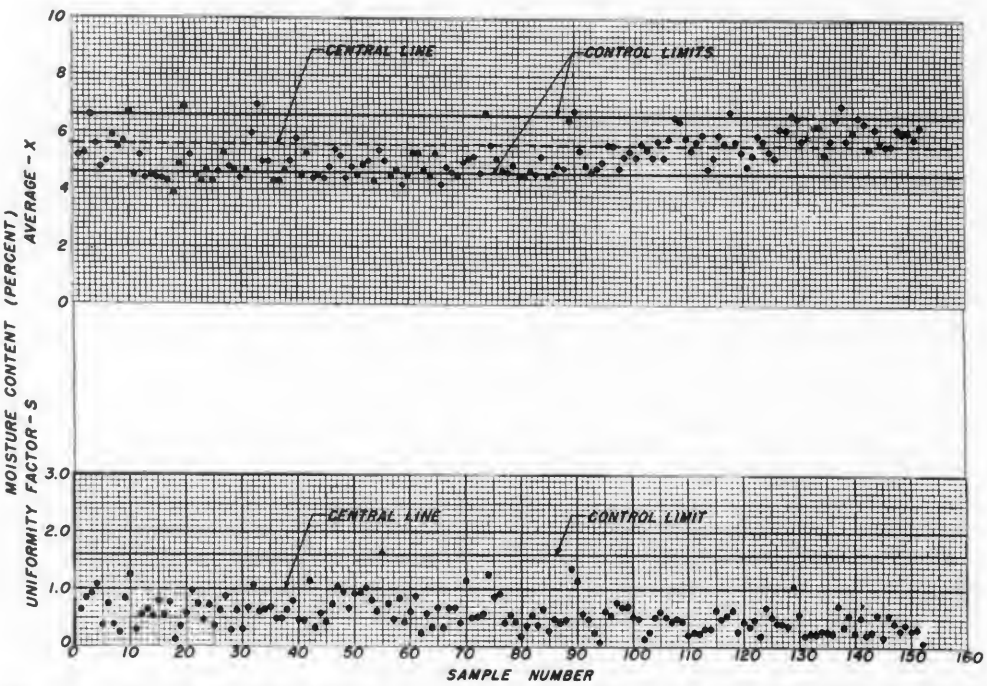

Fig. 3.—Control chart for daily sampling. n = 10; X^1 = 5.6 percent; S^1 = 1.0. Control limits for average = 4.6 and 6.6 percent; control limit for uniformity factor = 1.6.

from Forest Products Laboratory Report R1685 with terminology adapted by Rietz for the control of moisture content of lumber going into furniture production. The uniformity factor corresponds to the standard deviation used in the standard statistical procedures for the analysis of variance. There is some question whether usual statistical terms should be changed in this case. Regardless of this technical point, the use of control charts does show up the cases when drying is out of control and indicates when changes should be made in stacking or drying methods and when the process should be left alone. Anyone interested in consistently obtaining uniform moisture content lumber should thoroughly investigate the possibilities of this method for solving one of the most vexing problems of the wood industry. Statistical quality control is a new and valuable tool for controlling the quality of lumber seasoning.

Machining

After lumber is dried, it must be machined to the sizes and shapes required for the furniture being manufactured. The proper maintenance and operation of machinery is a fundamental requirement in maintaining a definite standard of quality (6). Most furniture plants do not supply the workmen or inspectors with enough specifications or checking jigs to guarantee constant quality in machining. It is suggested that the establishment of definite written tolerances for machining parts be undertaken as a long term project for the furniture industry. With such information plus metal checking jigs or gauges, workmen and inspectors can check set-ups and machined parts to see that the parts will conform to the standards set by top management. In addition, statistical quality control is dependent upon the use of definite tolerances. There are indications that the proper application of statistical quality control to machining operations may produce some of the most startling developments that have ever occurred in the woodworking industry. Mr. S. M. Nickey, Jr., Vice President of Nickey Brothers, Inc., Memphis, Tenn., has stated that his company has not received one serious customer com-

plaint since his company installed statistical quality control in their plant operations.

Statistical quality control is such a new development not only in furniture manufacturing but in all types of industry that it would be presumptuous for the authors of this paper to make any exact statements as to what this techtechnique can do to improve quality control of machined wood parts. However, a brief statement of the purposes and results in other industries should give an indication of what the possibilities are for the furniture industry. Grant (1) states that most engineers, production men, and inspectors must take an entirely new point of view in order to use properly the Shewart control charts for statistical quality control. This point of view is that any production and inspection operation is subject to some stable pattern of variation due to chance but variations outside this pattern can be located and corrected. The Shewart control chart enables one to identify these assignable causes of quality variation so that corrective measures can be taken in production operations. By also identifying those quality variations due to chance, the chart tells when to leave a process alone. It should be possible to develop the use of this technique in machining wood parts so that variations in machining due to such an item as different densities in the same species would be identified as due to chance. Variations in machining due to a worn bearing might be separated out by the control chart so that the machine would be repaired before actual defective parts would be produced. The installation of statistical quality control for machined parts would be an extremely complicated and difficult undertaking for any furniture plant; but the possibilities for obtaining uniform quality at reduced cost are so outstanding that this technique merits serious consideration by furniture companies.

Veneer and Gluing Operations

The selection and use of face veneer is a highly specialized phase of furniture manufacture. Many plants have excellent quality control in their face veneer operations through close coordination of purchasing and face veneer production. Good face veneer equipment combined with a certain percent of highly skilled workmen should produce the face veneers that will create the effect desired in the finished furniture. Both the face veneer production men and face veneer inspectors must be supplied with written specifications and samples in order to produce a consistently uniform quality of appearance in the finished furniture.

The control of quality in gluing operations is a subject big enough for an entire paper (7). Considerable study and experimentation should precede the specification for the kind of glues to use and the method of operation. If the wrong technical information is used, erratic gluing results will occur even though the workmen follow instructions explicitly. It is suggested that the production department keep records of glue mixes, temperatures, times, pressures, and other factors controlled in gluing operations. In addition, spot checks, by inspectors, of glue mixes, spreads, and trim from panels and edge-glued stock will indicate whether quality is being maintained. If a laboratory is available, these checks can well be made by the laboratory.

Sanding

The quality of sanding depends upon good equipment, the proper grits used and good workmanship. It is difficult to determine visually when a piece of wood is sanded properly. An inspector assigned to the sanding department must be an expert judge of a sanded surface and at the same time a diplomat so that he can obtain cooperation from sanding machine operators. It is hoped that there will some day be a technical method for determining a properly sanded or machined surface. Patronsky (8) has reported on experiments of this nature which appear promising, but at present furniture plants must rely on individual judgment of workers and inspectors.

Assembly

The cabinet rooms of furniture plants vary a great deal in methods of operation. Some plants have assembly lines where each semiskilled workman performs a single operation. In this type plant, the inspector at the end of the assembly line has an extremely important job. He must see that the assembled article conforms to specifications and must see that mistakes are corrected by the proper individual. However, in a furniture plant where the entire

fitting of a case is done by one highly skilled man, it is possible to have him perform the most of the inspection job while the final inspector checks for certain miscellaneous items.

Finishing

Controlling quality in finishing has been well covered by Walker (9). He states that quality standards must be established by the furniture company. The material specifications can be set by the furniture company in cooperation with the finishing material suppliers. The method of application must be set up by the furniture manufacturer and the finishing material suppliers. When these steps are completed, the production personnel and the inspection department should be given written instructions, oral supplements, and samples to follow so that a consistent standard of quality can be maintained. The final inspector must be a person of sound judgment and discrimination. He must be able to interpret specifications and be able to distinguish merchandise which will conform to the quality standards of his company.

Packing and Shipping

Packing and shipping do not contribute to the manufacture of a piece of furniture but they are so important to a furniture manufacturing business that it was thought that the subject should be included here. If a piece of furniture is carefully produced to definite quality standards but is later damaged due to poor packing, the effect is just as disastrous to the furniture company as if the product had been improperly manufactured. Ware (10) summarized the control of quality in packing and shipping as follows:

"1. Correct design
2. Performance or laboratory tests
3. Written standards for material and application
4. Proper supervision
5. Proper marking
6. Constant vigilance of your own and public carrier handling."

If the above procedures are properly carried out, most plants should not need a full time inspector of the packaging and loading operations. However, spot checks by the inspection department should prove valuable in seeing that the shipping department is conforming to standards so that properly manufactured furniture will reach the consumer undamaged.

Conclusions

Furniture plants in the southeastern United States have wide variations in methods used to control quality. Although many plants do produce products of uniform quality, many other plants could obtain better control of quality by establishing an organization for quality control, setting of definite written quality standards, and the use of statistical techniques recently brought into the woodworking industry.

There are correct principles and practices of quality control that should be applied in every department of a furniture plant in order to maintain uniform quality. These practices should be well established before new statistical techniques are applied. A new method for improving good operations will practically never be a "cure-all" for the ailments of a badly run plant. Statistical quality control is no exception to this rule; but this new technique does give indications of being one of the outstanding developments of our time for improving quality control in a plant that already is producing furniture uniformly to definite standards.

This paper has covered most of the phases of quality control in furniture production but has left out the most important item. The paper described how a furniture plant should organize for quality control and how each department should operate to maintain quality standards. Statistical quality control was described as a technique for furniture plants to consider as offering possibilities for extraordinary improvements in furniture operations. Unfortunately a plant can install such a theoretically perfect system of quality control but there will be very erratic and perhaps disastrous results *if the workers and supervisors are not quality minded.* When the top executives have a sincere interest in quality control, quality mindedness can then be passed down through intermediate supervisors to the man at the machine. When the entire organization is quality minded, the inspection system, the use of standards, the gauges and rules and the control charts can be made to function as they were designed; to in-

sure that the furniture will be produced at the planned cost and will conform to the standards set by the company.

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Defect Detection Equipment

Robert E. Partch

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Defect detection equipment—less a present reality than a future possibility in the wood industries—is defined and is compared to wood testing apparatus or machinery. X-ray testing methods are discussed. An automatic radio-frequency moisture detection machine is described. A laboratory method is discussed in which infrared rays are used to predict the fibre direction in wood.

DEFECTS in wood may be broadly defined as any imperfections or deviations from the normal fibrous structure that render it imperfect for a given use. Thus "defect" is a relative term: knots may be no defect in decorative knotty pine; clear, faultless wood, if cross or spiral grain be present, may be defective for certain uses. A certain moisture content may be a defect.

The detection of defects may therefore embrace the search for almost any physical or even chemical characteristic of the wood or wood product. Equipment for this purpose may be intended for inspection of wood on an industrial or production scale, as compared with studies of random or selected samples in the laboratory. The apparatus or equipment of the laboratory used in testing wood may be destructive or nondestructive of the material being tested; the methods may be slow or quick. Production or large-scale testing equipment must be nondestructive and reasonably quick. The usual mechanical or chemical methods of testing and studying wood seem inadequate.

X-Ray

The x-ray offers interesting possibilities. An apparatus and a method for inspecting public utility poles have been known for several years.[1] The purpose was to radiograph decayed or partly decayed poles whose density, and therefore capacity to x-rays, had been diminished. Apparatus has also been designed for underwater radiography to inspect piling for evidence of attack by marine organisms. X-rays lend themselves also to detecting nails, bullets, or other metal objects imbedded in wood and likely to cause damage to woodworking tools; a fluoroscope permits rapid visual inspection and renders radiography unnecessary. Completely automatic radiographic equipment is now available to the metal and paper industries for testing the materials for thickness. The apparatus for measuring the thickness of paper is making use of radioactive isotopes produced by the Atomic Energy Commission.

For many years x-rays have proved useful in examining paintings, whether on wood or other materials. Such wood panels, examined by radiography, may in themselves give clues as to the paintings thereon, depending on the type of defects discovered. A better example in art objects is furniture, showing evidence of "worm holes". These, if genuine, will have been caused by the larvae of insects, whose winding galleries are detected within the wood by the x-ray. An example of a genuine larva gallery can be seen in Fig. 1, in the dark portion of the radiograph. The concentric lines show the gallery of a particular type of larva that swings its head from side to side as it eats its way through the wood. A museum with ade-

Fig. 1.—Radiograph of incense-cedar 2½ inches thick, containing worm holes, split, and peck *(Polyperus amarus)*. One side when viewed appears as sound wood.

[1] Zucker, Myron. The Technique of Inspecting Wood Poles by X-Ray. ASTM Bulletin 120: 19–26.

quate equipment and technical personnel can readily distinguish such galleries from the artificial holes made by unscrupulous imitators.

The equipment or its adjustment needed for such varied applications is diverse. The radiography of heavy piling under water and of thin wooden panels, usually very dry, represent opposite extremes, with different voltage and other requirements. Procedures for the use of high-voltage "hard" x-rays are more common than procedures for low-voltage "soft" rays. These latter are useful in radiography of wood, especially dry, thin pieces, which because of their porosity, low density, and thinness, offer slight resistance to the "hard" short waves (Fig. 2). Negatives so produced have detail in

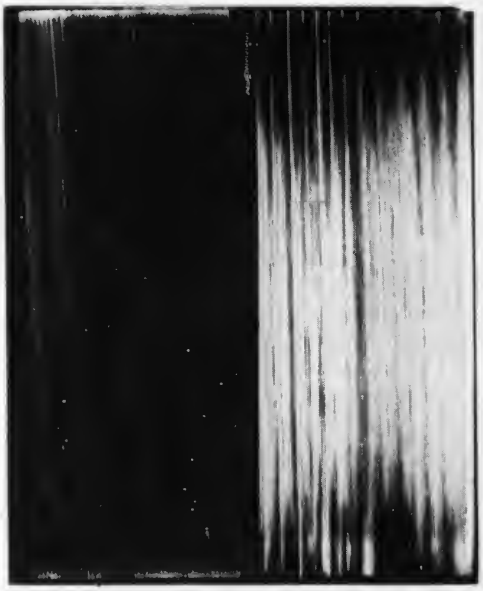

Fig. 2.—Radiograph of two pencil slats of incense-cedar (5 millimeters thick) containing moisture. The darker, close-grained slat had just been pressure-impregnated with stain. The other slat had the same treatment, but was partially dried. Note high moisture content in the summer growth.

part, but may be underexposed in other parts or in general. Frequently a second exposure, immediately following the first, is made, using a shorter wave length (higher voltage) and a shorter time. Some procedures call for five or more such consecutive exposures of the negative for obtaining detail and density in the negative of a very thin piece of wood, or even paper.

When the voltage is reduced below about 25 megavolts, the resulting rays become progressively less able to affect the negative, regardless of the time of exposure. The rays themselves have the ability to penetrate the wood, but they are unable to escape the glass envelope of the x-ray tube. To overcome this and utilize these soft rays, a tube with copper anode and beryllium window could be used. Such a tube would generate the soft rays at relatively low voltages and permit their escape to the material under examination. Fig. 3 is a radiograph of thin

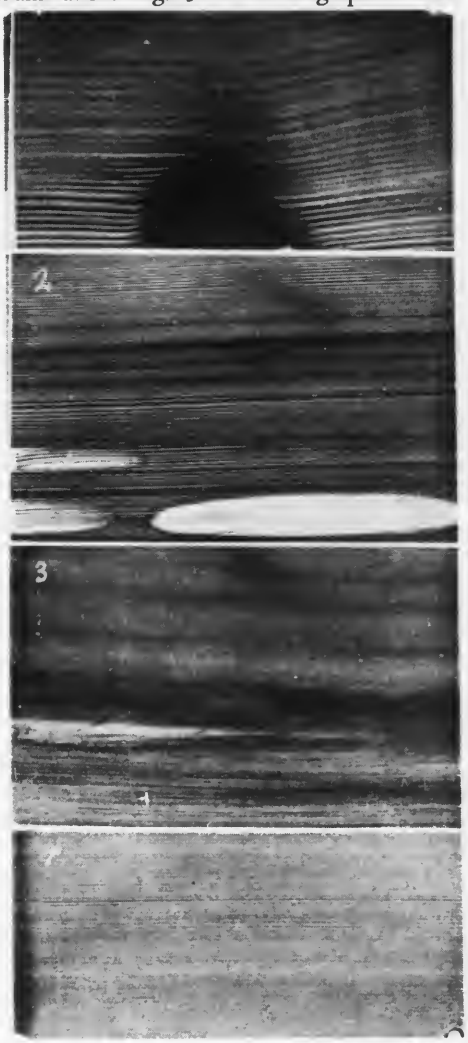

Fig. 3.—Radiograph of incense-cedar pencil slats showing grain, peck, *Polyperus amarus* and hard knots.

pieces of incense-cedar (5 millimeters) made by E. W. Philleo, of the General Electric X-ray Corp., who supplied the apparatus and suggested the proper technique for the radiography of thin, low-density material.

Radio-Frequency

Radio-frequency waves have been used for many years to measure the moisture in wood. Actually the dielectric value of the material is sought, and is measured by moisture meters made commercially for pencil use or designed for specific purposes. This value, however, depends also on the thickness or other dimensions, especially when thin pieces are tested. For these it is better to use two electrodes, placing the piece between them. If the electric current so obtained be balanced simultaneously against the current resulting from two similar electrodes across an air gap at a distance exactly equal to the thickness of the wood, this thickness variable is eliminated.[2]

The species of wood and other characteristics of the tested piece affecting density must also be considered. Dense wood, having relatively less air space, has a higher dielectric constant than light wood, disregarding moisture. Nevertheless, wood of high density, whether due to species or variations within the species, will have more absolute moisture than low-density wood, at equal moisture content, expressed as percent of oven-dry weight. Low moisture content of very dense wood will therefore affect the measuring instrument as does a lower-density piece of higher moisture percentage.

While a knowledge of the average density of wood species has been used to calibrate moisture meters or to make charts helpful in translating their readings to percentage moisture content, little has been published regarding the effect on such meters of variations due to defects, original position in the tree, and other aspects. Radiography may also be useful in the fundamental studies of the movement of moisture in wood (Fig. 2). The light areas represent areas of high moisture content. Such study will show the variation of moisture content in adjacent areas as between the summer and spring growth wood.

[2] Hagan, Owen. Patent Pending.

In spite of difficulties, moisture-detecting devices are useful and lend themselves to automatic inspecting machinery. For example, the so-called "Hydrojects"[3] for inspecting pencil slats have been in successful operation for about 10 years. These slats consist of pieces of incense-cedar (*Libocedrus decurrens*) sawn in dimensions of about 5 by 65 by 185 millimeters. They are dyed in an autoclave, absorbing more than 100 percent moisture, then dried in kilns, and later fed into the "Hydrojects." Each "Hydroject" conveys the slats, at the rate of up to 8 slats per second, past a moisture-detecting device. The resulting electrical change is amplified and relayed to all ejecting mechanisms, which can be adjusted to function at a predetermined impulse. Thus slats which exceed an established normal moisture content are ejected and can be dried further. Slats under a given moisture content are not ejected, but could be. Such apparatus is not restricted to measuring the moisture in each entire slat. Suitable machine design will permit measuring parts of each slat, such as zones near the ends or at the middle. Thus slats, that are not uniform in moisture content could be separated from those that are, automatically. The continuous inspection of pencil slats for moisture content constitutes a kind of automatic quality control which might be appropriate for other forest products.

Incorrect dimensions of wood may be regarded as defects. These can be rapidly measured by mechanical or photoelectric means, and the results translated by mechanical action or electric recording devices, oscillograph screens, and so forth. In the pencil-slat inspection machines already described, the "Hydrojects". an additional station provides a mechanical contact-measuring device which in turn actuates an ejecting mechanism when the slat thickness is less, and also if desired more, than a predetermined normal. By means of screw adjustment and micro-switches, the device is accurate to less than 0.1 millimeter.

A method has been discovered[4] by which compression wood can be detected by transmitted visible light viewed through a thin cross

[3] Wilcox, William. Patent No. 2,228,901.

[4] Pillow, M. Y. A New Method of Detecting Compression Wood. Jour. Forestry, Vol. 39, No. 4.

section. This method, however, does not lend itself to automatic means, because prior selection and preparation of samples is necessary, and the method therefore is unsuited for the detection of defects in random pieces or in continuous quality control. Nevertheless the study of transmitted light in the visible and infrared bands shows a bending of the light in the direction of the wood fibers.

Fig. 4 is a photograph of three specially prepared samples of wood containing diagonal fibers. These slats were placed over an opening at one end of a light-tight box, and a small, bright, circular spot of light was projected on the outer surface at the intersection of cross hairs placed just behind the slat, inside the box. The cross hairs were placed square with the edges of the slats. The infrared light penetrated the slat and emerged in an elliptical shape. The long axis of the ellipse is always in the direction of the fibers, because the light is more easily transmitted down through the hollow central portion of the fibers than across them. This emerging invisible beam was photographed with infrared film, and the corresponding photograph placed above each slat. The slats were then broken as shown, and the breaks were in the direction predicted by the

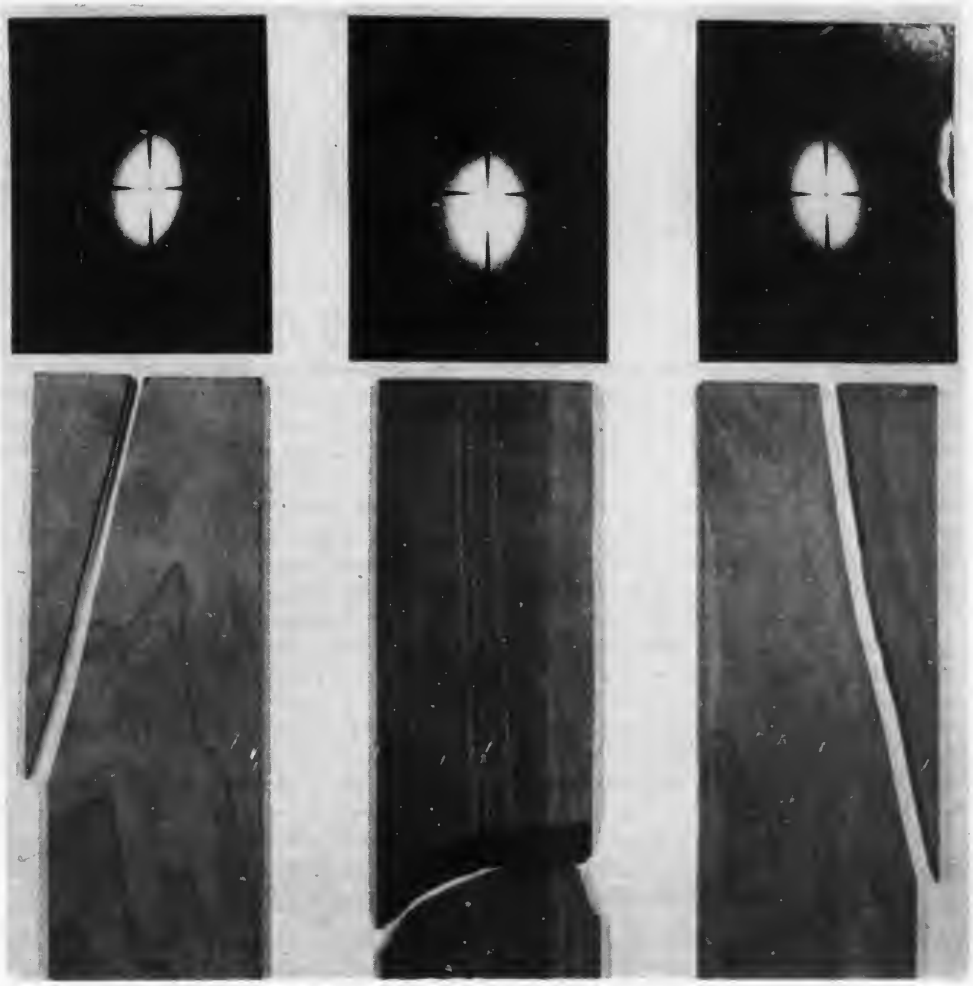

Fig. 4.—Infrared photographs predict how wood will split.

ellipse. The central slat, "B", containing short grain, displaced the ellipse below the horizontal wire in the cross hair, showing the tendency of the fibers to conduct the light in their direction. This phenomenon should be useful in predicting how a piece of wood will split, and could be used as a non-destructive means of testing pencil slats and possible veneers.

Laboratory apparatus has been designed and tested[5] to show this effect on a graph, prepared electrically. Wood having cross grain or spiral grain can thus be identified in a way analogous to the ink and scribe tests already published.[6] These experiments have not proceeded far enough to furnish detailed data nor to design production equipment. Laboratory equipment includes a photoelectric cell sensitive in the infrared range, since in a slat about 5 millimeters thick a high percentage of the visible light, especially of the shorter wave lengths, is absorbed or reflected. The transmitted light, including the infrared, which impinges on the cell, is related to the optical density of the wood, within the range of the cell's sensitivity. As the slat is moved mechanically between the light source and the cell, zones of varying optical density in the slat can be observed on a meter connected through an amplifier to the cell and recorded on graph paper by an electrically operated pen. Knots, bark, decayed zones, and other defects are recorded on the graph paper, as well as the direction of the fibers.

[5] Hagan, Owen. Patent Pending.

[6] Koehler, Arthur. Guide to Determining Slope of Grain in Lumber and Veneer. U. S. Forest Products Laboratory Rept. No. 1585.

Discussion

Mr. J. F. Hamilton (Perkins Glue Co.): Would it be possible to segregate core or solid lumber dimension into low, medium, and high density ranges by electronic methods?

Mr. Partch: Wood has a dielectric constant of approximately 4 to 7, and water has a dielectric constant of 81. Therefore, moisture will have a much greater effect on the dielectric constant than the density of the wood itself. However, in practice this could be an advantage, because the high density wood may have a tendency to contain more moisture, due to its inclination to dry more slowly than wood of lower density. In practice it would be necessary to make limited tests and evaluate these tests in terms of the result desired. As an example, a machine that automatically detects the moisture content of wood may not be as accurate as desired in terms of moisture content of dry weight. It still may be practical from a commercial standpoint because of its ability to detect wet spots.

Mr. A. H. Rauch (Plywood Research Foundation): Could the California Cedar Products Company infrared detection method be used in detecting blisters or poorly bonded areas in plywood panels?

Mr. Partch: Because the fibres of wood distort the rays of light emerging from a test specimen, each type of wood or dimension should have a standard pattern, provided the fibres themselves are lying on the same planes. This pattern usually emerges in elliptical shape if the ingoing source is circular in shape. If the specimen is made up of several layers, this emerging pattern would then assume a new shape for this new set of conditions.

In other words, each type of specimen will have a pattern considered normal for that type, and any deviation from this normal would indicate an abnormality in the specimen itself. As plywood contains two or more layers normally bonded together tightly, one would expect that an air space would alter this normal pattern and could be detected automatically. There are many factors concerned, such as types of surface, thickness of specimen, type of wood, type of glue, speed of operation, moisture content, defects in wood, etc., and no definite information could be given without sufficient research on any particular application.

Quality Control in Relation to Labor

Robert T. Borth

Manager, Community Relations, General Electric Company

The nine-point job program of General Electric Co. is fully described. The program represents the company's effort to meet the expectations of employees regarding their jobs. Starting with a survey of employee attitudes about the company and about their jobs, the company condensed the findings into nine basic elements that employees expected out of their jobs in return for their full skill, care, and effort in the performance of their daily work. The program is described from the standpoint of its effect on the quality of the company's products, that element of quality control which reaches beyond technology and into the attitude realm of workers.

IT IS a pleasure to be here and to have the opportunity to address you. I am not a technical man in your field. You have already heard qualified speakers on technical matters about which you are concerned. It is my desire, therefore, to talk to you with an altogether different approach to the considerations of quality control.

The company that I represent—General Electric—regularly observes the technical needs in achieving quality control. It is responsible, as a matter of fact, for the conception, the research for, and the development of a great number of devices and techniques which have that sole purpose.

The ingenuity, persistence, and the imagination of the engineers responsible for the developments in our research laboratory and in the factories make a fascinating record, full of inspiration and compel admiration.

The General Electric objective to provide more and better things for better living for everyone is more—much more—than a slogan —it is a philosophy of being—an end in itself.

There are the scorners, I might add, who point to the fact that man is no better off because he has more refrigerators, more electric fans and blankets, more light, more heat—perhaps not, but his life is easier because of them —and he feels better about living because of them—and scorners certainly are not rejecting either for themselves.

You are well acquainted with the great number of devices used in setting up good quality controls and I will not, therefore, go any further with discussion in that direction.

But about easier living and of better feeling I intend to say something more—that is, as it relates to quality control.

For all of its nearly 60 years of existence, General Electric without question has made quality control for its products a prime requisite, and it has a record in this regard for which, as I have already gently hinted, it feels considerable pride—quality control that grows out of the application of technical principles.

There came the day, however, when it was clear that something more than technical considerations were needed—even though those technical considerations had yielded many fruits and would continue to yield even more fruits.

But it became increasingly certain that to enlarge productivity of the individual, technical applications were not enough—something more should be done—another ingredient added.

The question then arose as to what ingredient was needed over and above technology that would push productivity toward the maximum that would provide more people with more goods at relatively less cost.

People and their attitudes, of course! They run the machines. Their productivity helps create wealth for all—their skills are the ultimate quality controls. If the men and women in the plants were unwilling to remain at work steadily, and were indifferent to the quality of the products they helped produce, production and quality were bound to suffer—and they did.

There are a number of reasons for post-war attitudes of workers in the plants—consequences rising out of the exigencies of war conditions and the lesser quality of workers absorbed under wartime manpower shortages, etc.—but these matters are not part of the point I wish now to make.

What General Electric wanted to stimulate was this matter of the workers "feeling better" —feeling better about their jobs, and their

wages, and their working conditions, and their bosses, and their employer.

This, we believed, wholly apart from the spiritual values, would mean the difference between average quality and top quality of the products the workers helped to make. It would get at that percentage of improvement not touchable by technology.

The next problem was how to attain that "better feeling" of employees. What was it that could be done by the company to make them understand how important to their economic welfare was their own productivity—how important it was to their economic welfare to produce goods that were better in quality than our competitors,—how to make them understand that this meant continuing jobs for them and better wages—all the benefits of working for a thriving enterprise—and their individual economic success.

Having decided to seek a solution, General Electric first sought to learn from the employees' own lips what would make them "feel better" about their jobs—and to learn where the company had failed them in providing what they expected of their jobs.

The company already possessed two things that were needed to stay in business and to remain successful in business—it was the third element that we lacked and which we were striving to achieve. We had, for one thing, satisfied product customers—our products were considered good in quality and fair in price.

We had the second thing needed—satisfied stockholders—they thought we were running the business well and that the return for their risk was reasonable.

But the third thing—satisfied job customers—we did not have. Employees thought the management incompetent at running the business, that the business was being operated in a way that was against the interest of the employees, that our profits were stolen, and that we were a dishonest, selfish, money-grabbing lot without a decent regard for our responsibilities to individual employees or for our civic obligations.

In determining what it was the employees expected their jobs to provide, we employed established methods. For example, in the product field we had learned the wisdom of exhaustive search and objective accuracy in determining what the customer wants, why he thinks he wants it or wants it a certain way, when he wants it, how much he thinks it is worth, and how he wants it delivered.

We had also learned the value of finding out how right or wrong the customer is in his understanding of the present possibilities for supplying what he desires or expects. We learned how to take advantage of all this information in devising the kind of a product the customer wants. And we learned how to do it within the price the customer can and will pay.

In this same way we sought the employee's likes and dislikes about his job; what he understands, misunderstands, or just doesn't know about his job. We have inquired into what he does and does not understand about the social and economic influences which surround his job with opportunities and limitations.

We looked for the motives and beliefs which determine whether or not he will come to work promptly, regularly, and in an agreeable mood; the things that determine whether or not he will give his full skill, care, and effort while working; and the events and impressions that determine whether or not he will go home reasonably satisfied with his associations and accomplishments at the end of the day.

Our investigations into what the employee expected of his job brought out nine basic points—and if some of you have heard about General Electric's nine-point job, this is what is meant by it. I will describe now those nine expectations of the employee, and with each of them I will explain what the company is doing to fulfill his desires.

Employees said they expected from their jobs:

1. Pay that is right—all things considered—for the skill, care and full day's effort as measured by reasonable modern standards; also, extra financial benefits such as pensions; awards for ideas, free life insurance, scholarships, and paid vacations.

How we are meeting this expectation: Our wages and salaries are in line with comparable jobs in our plant communities. We provide the extra financial benefits, including a good and fair pension program; a liberal life insurance plan; health insurance and hospitalization plans; paid vacations and holidays; awards for suggestions and ideas; scholarship awards; fel-

lowship awards; a savings plan that provides a 15 percent bonus of G–E stock; relief and loan plans; special recognition, such as our annual Coffin Awards honoring deeds of outstanding merit.

2. Working conditions that are as good as they can be made at the moment, that are regularly improved, constantly studied for further improvements, and about which suggestions from employees are welcomed; well-run plant conveniences, such as cafeterias and parking lots, and the like.

How we are meeting this expectation:

We have had an outstanding record for many years and we are constantly improving the working conditions. Many of our plants have won safety awards from the National Safety Council, and our company safety record is in the upper brackets. We are striving to improve and extend cafeteria services, parking areas, recreational facilities—all those things that employees consider valuable to them.

3. Supervision that is technically competent, competent as leaders, and competent as counsellors wherever personal aid is sought by employees.

What we are doing about this expectation:

We provide our approximately 15,000 supervisors with regular data about company policies, plans, and operations. We distribute to them weekly bulletins that keep them informed about important subjects affecting the interests of employees, such as data about economic matters, social developments, union negotiations, of plans for new activities. Our managers conduct forums, conferences, and meeting with supervisors and foremen to discuss information about the company's affairs, so that each, in turn may be in a position to do likewise with his employees. Employee newspapers print personally signed management messages on plant affairs. We provide opportunities for the development of technical skills of supervisors. We encourage and actively aid supervisors to develop as leaders by training courses that, among other things, place particular emphasis on the duties and responsibilities relating to "human considerations" in the performance of their responsibilities. We strive in every way to make them better bosses—not drivers.

4. Job security to the greatest possible degree as the result of teamwork of employees, management, stockholders, and customers.

What we are doing about this expectation:

We have taken positive action with this aim in view, such as scheduling of production wherever possible in such a way as to maintain year-round production on seasonal products. We are constantly extending more care in planning manufacturing and sales that will lead to stability of operations and thus to steadiness of jobs. We do everything possible to hold layoffs to a minimum by shifting workers to other jobs.

5. Respect for basic human dignity.

What we are doing to meet this expectation:

We constantly counsel supervisors, particularly through group meetings, about the spiritual values employees expect from their jobs and we instruct them in how to "put the human considerations first."

In the same spirit, we practice in all phases of the company's relationship with employees those acts and that behavior which reflect our respect for each employee as an individual.

6. Promotion as fast as there are opportunities and on a strictly fair basis, and that individual ability and ambition be aided as much as possible through training on the job.

How we meet this expectation of employees:

Our policy is to promote employees to the greatest possible extent, and to do so with strict fairness. Great numbers of our management and supervisory force has passed through the ranks, including President Wilson, who started in G–E shops more than 50 years ago. Many thousands of our employees are participating in company training programs for their future advancement.

7. Information on management's objectives, policies, problems, plans, successes and failures, and current expectations for the section, department, and company as a whole. Information about economics, social affairs, and other subjects as they relate to employee interests.

What we are doing about this expectation:

We conduct an all-out program for providing employees with information, including company policies, activities, and plans. Informational data of all kinds is regularly printed in

employee newspapers, bulletins, and magazines. Supervisors and managers hold informative meetings with groups of employees to discuss everything with which employees are concerned. We provide full information on production and sales, profits, and our prospects for the immediate and distant future. We send letters and other literature to employees' homes to keep them and their families informed about pertinent subjects. We place great emphasis on what we call two-way communication. We want the opinions and attitudes and wants of employees to be known by all management levels.

8. Belief in the importance of the individual's job, in its significance and challenge, and in the employee's contributions to the worth of the final G–E product.

How we are meeting this expectation:

We try in every way to have the employees appreciate how their jobs relate to the product as a whole. We provide him with the opportunity to see other sections of the plants so that he can relate his activities to the combined efforts—to understand how his job plays a part. We endeavor to wipe out any notions that the company considers any job unimportant or the doer of the job as insignificant.

We strive to teach the employee to understand that all parts of a product are vital to the finished product. We constantly remind him that the products to which he contributes are used by himself and his neighbors and that they contribute to a more comfortable standard of living for all.

9. Satisfaction that comes from being home with the family after a day's work and having the feeling that something worthwhile has been accomplished by his day's work; that the accomplishment has gained the attention and earned the respect and gratitude of his fellow employees at all levels, and that the job is a good one to return to the next day and on following days.

How we are meeting this expectation:

We express our appreciation of the employee's efforts by every means at our disposal. We seek to have foremen and supervisors try to make the employee understand that we appreciate his good work.

We emphasize that the quality of the work makes it possible for the company to compete successfully with other makes of a similar product, and that the individual's work is the cause of the confidence or lack of it placed on G–E products by customers; that the employee can make or break G–E's reputation of quality by the good or bad results of his work.

We are working hard to nurture the wanted nine-point job into full bloom. We are wholly satisfied that it is right, and we want to do right voluntarily.

We are well embarked upon our course now and have been working on the policy of putting "the human considerations first" long enough to satisfy us about its values.

There is another important side of our activities that I will describe briefly. It belongs intimately to the nine-point job. This is our simultaneous effort to supply the neighbors of our plant communities with the same information given to our employees.

We recognize that an employee may leave the plant at the end of a day satisfied with his work and with his boss and with the company, but after mingling with his family and neighbors he may, through their attitudes, doubt the satisfactions he felt when he left the plant for the night. Their uninformed attitudes, where they may be unfavorable about the company, unquestionably affect his point of view; his own feelings.

We feel that if the whole community, as well as the employee's family and friends and neighbors have the same facts, and the opportunity to judge G–E from these facts, that an atmosphere would grow in the community which would tend to support the employee's favorable views rather than to undermine them.

For this reason, we distribute throughout the community, literature that describes the company's working conditions, policies, operations, and informational data of all kinds. The plants, through paid advertising space in the local newspapers, print our messages, which frequently discuss controversial economic and social questions that are current and that affect employee interests. The same messages are printed in our publication, "The Commentator," distributed to all the thoughtful people in the community, such as the civic leaders, educators, clergy, other employers, and fraternal and other organizations.

The policy we follow, or point of view we hold, on any matter receives widespread dissemination. From this it is our hope that attitudes toward the company in every community will be based on knowledge rather than on ignorance—that the community will be able to determine for itself whether General Electric is living up to its announced policies and objectives.

We want to be a good neighbor and a good citizen in every community, as well as of the nation, and to be known as such. We want to do what is right, and we want everyone to know that we are fulfilling our obligations and responsibilities as an employer, as managers of the business, as a citizen, and as a neighbor.

We are fully aware that we must speak out for those things we believe in, and not meekly or arrogantly refuse to counter the strong voices that rail against business and against the present economic and competitive business system of the country.

We try in every way we can to present sound economic information and sound views on social actions that are proposed. We do everything we can to interest other employers and other organizations to take an active part in such activities.

But that is another story and extends beyond my theme for today.

Returning, however, to consideration of the nine-point job I have outlined, I would like to make some final observations.

We do not believe that our efforts have gone to waste. As a matter of fact, we have reassuring evidences of success about our policy of "putting the human considerations first."

I need hardly say that in launching the program described that it was not received enthusiastically by all people—the new responsibility, in many ways, amounts to a wholly new way of life. We are convinced that in isolated instances this new way of life will not take hold fully for perhaps another generation. Time alone will solve certain problems.

But in the importantly broad phases of our effort to create a new set of values we are moving steadily forward—even spectacularly forward in some areas.

We believe that the attitudes of our nearly 175,000 employees are improved—that they believe we of management are really on the employees' side.

We believe that our employees have a better understanding of the competitive enterprise system under which all of us work.

We believe that the attitudes in our plant cities are improved.

The test of the effectiveness of our program will come at the union negotiation tables, in the plants where our employees make our products, in the meeting places of citizens.

General Electric believes its program to be sound business, sound planning, sound principle, and also immensely effective in the quality of its products.

Discussion

Mr. J. Grant, Jr. (Burritt Lumber Sales Co., Inc.): What are you doing about the locations where the program is either not moving forward or not moving rapidly enough?

Mr. Borth: We carry on a continuous campaign throughout the Company to educate management and supervision about the necessity for carrying out the spirit and the letter of our 9-point Job Program.

Mr. G. E. Tower (Forest Fiber Products Company): Would you care to make any comment as to what you think is the relative importance of the 9-Point Program in the G. E. program—are human considerations more important or are economic considerations more important? For example are factors influencing the feeling of the individual worth more than wages paid?

Mr. Borth: The fundamental reason for creating a business is the hope of profit. Therefore, speaking basically, the first consideration of a business must be to operate in such a manner as will return a profit to its owners. In this sense, economic considerations may be said to hold first place. However, since business is operated by human beings and is directed by their intelligences and spirits and energies, and upon whom business depends for its success, human considerations must be placed on a par with economic considerations. There was a time in the earlier history of business and industry

when it advanced so rapidly technologically that human values were shunted into the background. But later, even though technological progress continued to advance, consideration for human factors in business and industry became more and more emphasized. Today there is no question that economic and human considerations are equally important. For example, no business can survive for long that attempts to disregard human beings in the manner that business once did. Any business has four great publics to satisfy—its customers, its employees, its stockholders, and the public at large. Without the good will of all of these, any business will soon fail.

We believe we should "put human considerations first", but in doing so, G. E. cannot ignore sound economic considerations any more than any other business can. The customer pays the bills and he compels us to make a quality product at less cost than our competitors; if we do not, he will buy our competitor's products. In the last analysis then, the customer determines whether or not we are going to stay in business. The skill of our employees and management determines whether or not we are going to satisfy our customers better than our competitors.

Mr. D. S. Smith (Oregon State College): Did the employee feel at any time that the employer was becoming paternalistic toward him?

Mr. Borth: I am sure I cannot say whether such a feeling did or did not exist. I can only give an opinion and that opinion is that there is no sound basis for thinking that the Company is being paternalistic toward the employees. The reason for this opinion is that the Company in establishing wage rates, salary levels, and benefit programs, such as pensions, insurance, hospitalization, etc., endeavors to be fair in all its actions. The Company needs employees—good employees—and to get them it must offer something more than competing employers offer them. Good employees and good management have made the Company successful, and because it is successful, it is unquestionably better able to act more generously. An unsuccessful business is not in a position either to be over-generous or, as a matter of fact, to remain around very long. We express these facts to our employees and to the public regularly and I think our actions are not considered "paternalistic".

Mr. R. Dingman (Klok Institute): Will the program work?

Mr. Borth: Yes, it is working. The record proves that we are getting rewards in production that are not attributable alone to technological developments. Improving quality in our products is another proof. A third factor of proof establishing the value of the program is our better relationships with employees; and a fourth is improved attitudes of the general public in our plant communities.

FOREST PRODUCTS RESEARCH SOCIETY

Nondestructive Testing for Forest Products

George Kitazawa

Wood Technologist, Timber Engineering Co., Washington, D. C.

The susceptibility of wood to mechanical vibration is the basis for the nondestructive test here described. The frequency of vibration is used as a measure of the stiffness of the wood items in test. Comparison of the stiffness values by the dynamic and static tests are presented.

Introduction

IN RECENT years nondestructive testing of materials as a means for rapid and comprehensive quality control has been evaluated in a number of research laboratories here and abroad. As its name denotes, nondestructive testing is actually an inspection of samples for defects or an over-all measurement of a physical property without subjecting such samples to destructive tests as is frequently the case in many testing procedures. Such inspection has, therefore, the singular advantage in that all items to be used in service can be examined, thereby eliminating the probability element connected with random sampling techniques frequently applied in quality control.

What are some nondestructive tests applicable to wood? These are primarily of two types, the detection of defects and the evaluation of stiffness or rigidity. The first includes X-ray examination of wood in which X rays are transmitted through the item in question revealing the varying densities and thicknesses in light and dark patterns. In such an examination, decay, wet areas, and metallic objects can be readily located. Another example of the same type of test is the search by mine-detectors for embedded nails in logs as practiced at many veneer and sawmills. The second type of nondestructive test for stiffness evaluation of wood by mechanical vibration is the subject of this paper.

Resonant Frequency

Wood like other elastic materials can be made to vibrate under impact or a forced external vibration of a suitable frequency known as the resonant frequency. This frequency can also be described as the value giving the maximum vibratory motion in an elastic body. Its numerical value will depend on the stiffness of wood, the density, physical dimensions, and the direction of vibration. The stiffness is usually expressed as the dynamic modulus of elasticity to distinguish it from the modulus of elasticity obtained by the standard static-testing procedures.

The xylophone illustrates the principle of resonance. When the wood bars are struck, the notes represent resonant frequencies in which the length of the bar controls the pitch. The stiffness of the bar is related to its pitch.

Although it would appear that many variables are involved in the resonant frequency determinations, a number of these can be eliminated by standardizing the size of the specimens to be tested as would normally be the case for a production item. When the shape and size are fixed from one sample to the next, the resonant frequency can be used as an index of the ratio of stiffness to density. Further, if density or weight is known, the modulus can then be expressed in terms of the resonant frequency. In the inspection of production items, two measurements are thus required, the resonant frequency and the weight of each sample.

To obtain resonant conditions two modes of vibration can be employed. The beam can be made to vibrate transversely in bending—such as would be the case of a lath held firmly at one end with the free end made to vibrate transversely upon flexure. For this cantilever setup, Hearmon (3) of the Forest Products Research Laboratory of England has carried out investigations on the relationship of the modulus of elasticity to resonant frequency.

The second mode of vibration is a longitudinal one in which the beam lengthens and shortens in vibration along the grain. For example, a wood beam struck a sharp blow on one end will emit a tone produced by this longitudinal vibration. This frequency is much

higher than the one generated by the transverse vibration of the same beam. The Forest Products Laboratory at Madison reports that the tone of hickory handles when dropped upright on a hard surface can be used as a qualitative measure for the grading of handles (4). This same laboratory has been carrying out studies to establish the relationships between dynamic and static testing.

Mathematical Relationships

In the literature on vibration of isotropic materials, equations have been derived for beams in transverse and longitudinal vibration. These equations are usually found in most books on sound and vibration, and therefore need not be treated in detail here. Most of these, however, do not take into consideration shear deformation and the anisotropic property of wood. Obert and Duvall (5) have summarized some of the correction factors that are involved for an isotropic material. The accuracy of the uncorrected equations, nevertheless, is sufficient for many purposes.

The basic relationship involving frequency, modulus and density is

$$f \propto \sqrt{\frac{E}{d}}$$

where f = natural resonant frequency
E = dynamic modulus of elasticity
and d = density

To equate the foregoing into an equation convenient for use, proportionality constants are determined whose values are derived from the size and shape of the wood item, and the mode of vibration. This equation becomes

$$E = kWf^2 \quad \text{----------I}$$

where E = dynamic modulus of elasticity in p.s.i.
k = a constant, the beam factor
W = total weight of the item in grams or pounds dependent on the k value used
and f = resonant frequency in cycles per second (c.p.s.)

The equations (2) used in calculating k for the two modes of vibration are presented. For transverse vibration,

$$f_L = C\sqrt{\frac{gE_LI}{wL^4}} \quad \text{----------II}$$

where f_L = natural resonant frequency in c.p.s. for transverse vibration
C = 3.56 for fundamental frequency of beams supported at 0.224L from each end
g = 386 in./sec.^{2}
E_L = dynamic modulus of elasticity in p.s.i.
I = moment of inertia in in.^{4}
w = weight of unit length beam in lb./in.
and L = beam length in inches

For longitudinal vibration,

$$f_{Lc} = \frac{n}{2L}\sqrt{\frac{gE_{Lc}}{d}} \quad \text{----------III}$$

where f_{Lc} = natural resonant frequency in c.p.s. for longitudinal vibration
n = 1 for fundamental frequency of beams supported at the midpoint
L = beam length in inches
g = 386 in./sec.^{2}
E_{Lc} = dynamic modulus of elasticity in p.s.i.
and d = density in lb./in.^{3}

Some beam factors evaluated from Equations II and III are listed in table 1. These are calculated for two standard size specimens used in the static testing of wood.

An illustrative example of the use of the beam constant in determining the dynamic

TABLE 1.—BEAM FACTOR CONSTANTS

Test beam size	Transverse vibration		Longitudinal vibration	
	Beam factor	Weight expressed in	Beam factor	Weight expressed in
Inches				
2x2x30	4.2	lb.	7.8×10^{-2}	lb.
	9.1×10^{-3}	grams	1.7×10^{-5}	grams
2x2x8	--------	--------	2.1×10^{-2}	lb.
	--------	--------	4.6×10^{-5}	grams

modulus of a standard beam 2x2x30 inches in size, weighing 2.0 pounds, and resonating at a frequency of 350 c.p.s., is given below:

$E = kWf^2$

$E = 4.2x2.0x350^2 = 1.0x10^6$ p.s.i.

In Equations II and III reference is made to the fundamental resonant frequency. Elastic materials when set into vibration do not vibrate at only one but at a number of frequencies which are multiples of the fundamental. The lowest component frequency is the fundamental and is the one sought in the application of the equations here described.

Equations II and III can be combined to give a relationship that will compare the two moduli, one for transverse and the other for longitudinal vibration. The relationship of the dynamic moduli to the resonant frequencies becomes

$$\frac{f_{Lc}}{f_L} = 7.3\sqrt{\frac{E_{Lc}}{E_L}}$$

or in terms of the moduli

$$\frac{E_{Lc}}{E_L} = 0.019\left(\frac{f_{Lc}}{f_L}\right)^2 \text{-------IV}$$

The foregoing reveals that for a 2x2x30-inch beam the longitudinal vibration frequency is 7.3 times the transverse for uncorrected conditions. In the static testing of wood, Equation IV is taken to be

$$\frac{E_{Lc}}{E_L} = 1.10 \text{ ----------V}^{(1)}$$

Vibration Equipment and Procedure

Fig. 1 is a schematic diagram of the apparatus and the methods for driving the beams. A calibrated variable frequency audio oscillator generates an alternating voltage that is amplified to drive the vibrator, either a dynamic loudspeaker or a condenser exciter.

The intensity of mechanical vibration is measured by the crystal pickup that converts the mechanical vibration of the beam into an electrical signal. This signal is fed into a voltage amplifier and the strengthened signal is projected on the screen of the oscilloscope. The electronic equipment is shown in Fig. 2.

For transverse vibration the beam is placed on the supports with the pickup positioned at the center of the beam (Fig. 3). The audio intensity is raised to a level sufficient to set the beam in vibration and the oscillator is tuned until the resonant frequency is reached as indicated by the maximum screen deflection on the scope. The reading on the dial and the weight of the beam are recorded.

In the case of longitudinal vibration the beam is stood on end on the plates of the condenser exciter (Fig. 4). When a high direct current voltage is placed across the two plates of this condenser, separated by a suitable insulator and excited by an alternating voltage, the condenser plates will repel and attract each other with the alternating voltage. Since the heavy base plate has been selected for high inertia, the light foil resting on top will be the plate creating the mechanical vibration. This vibration is transmitted directly to the upright beam. Although shown, midpoint supports are not necessary.

Conclusions

The dynamic moduli in transverse vibration as calculated by Equation I averaged about 10 percent higher than the static moduli. This difference has been found in tests made on a number of standard beams of different kinds of wood ranging in moisture content from 6 to 12 percent.

The dynamic moduli in longitudinal vibration cannot be compared to the static since a specimen of length-to-width ratio of 15 is involved. However, by comparing the dynamic moduli obtained in the two directions of vibration, it is possible to check the accuracy of the method. The average of values is about 1.1 for Equation IV and is in good agreement with the ratio given in Equation V for static moduli.

The transverse vibration method appears at this time to be the most flexible for the testing of wood products. Usually, no contact is required between the vibrator and the item in test, the vibrating air column being sufficient to drive the beam.

As mentioned in the beginning, this nondestructive test does not locate defects. However, the presence of major defects is made known by its effect on the modulus.

Much improvement in electronic design in present equipment assembled from standard

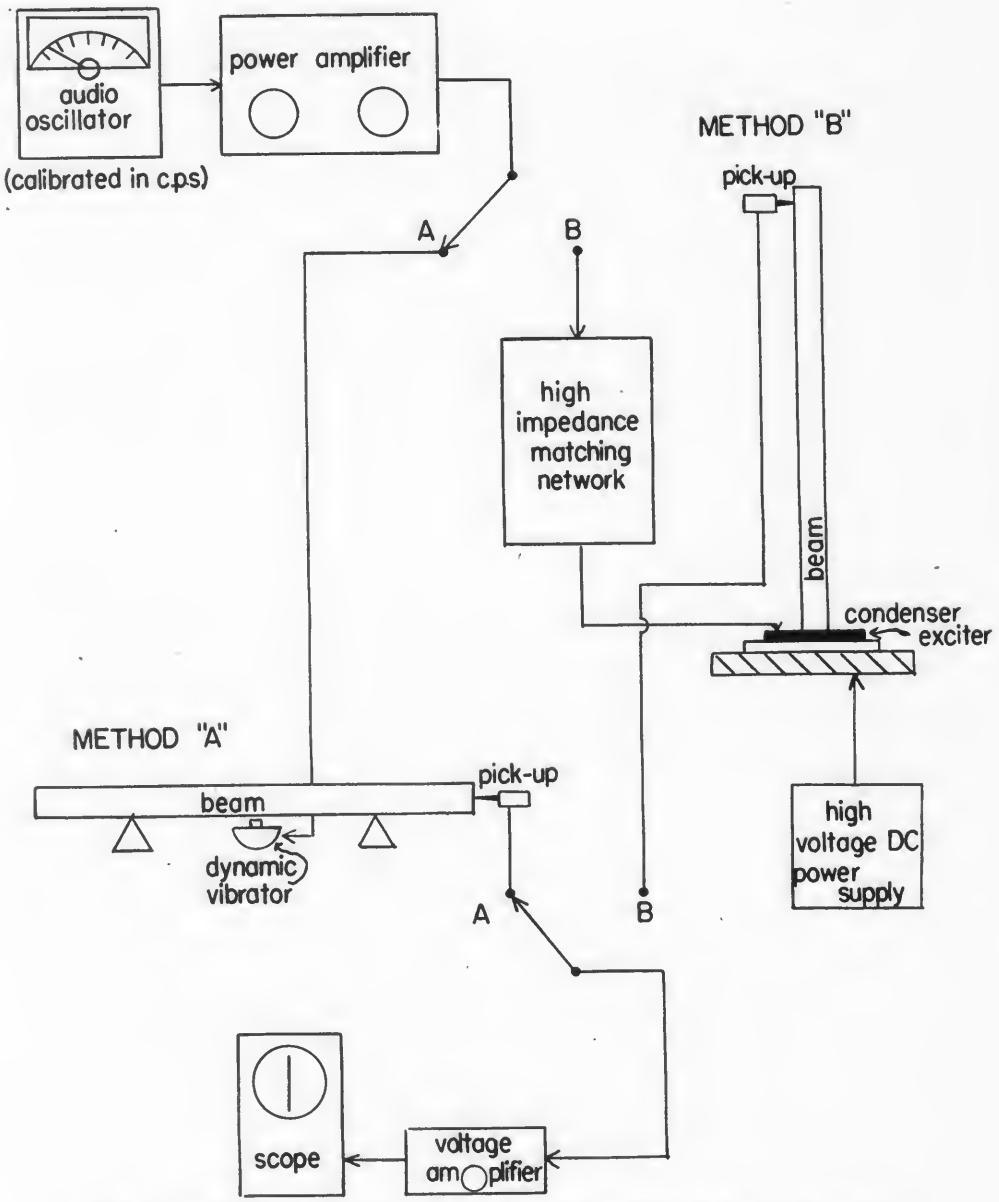

Fig. 1.—Schematic diagram of nondestructive testing equipment and methods of vibration.

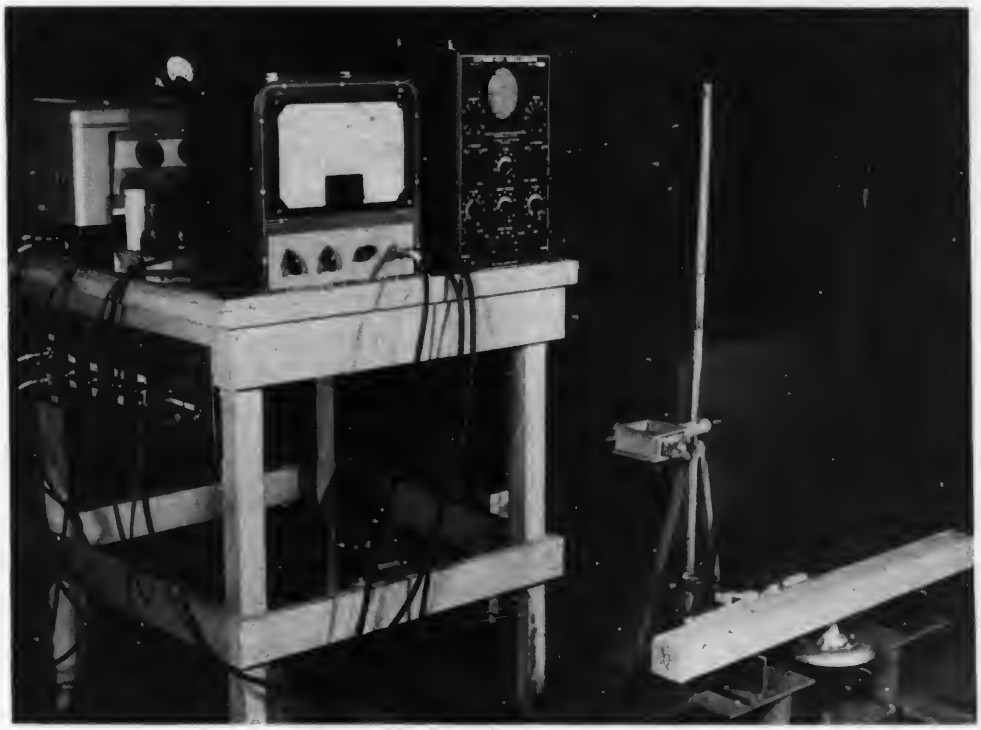

Fig. 2.—Nondestructive testing equipment.

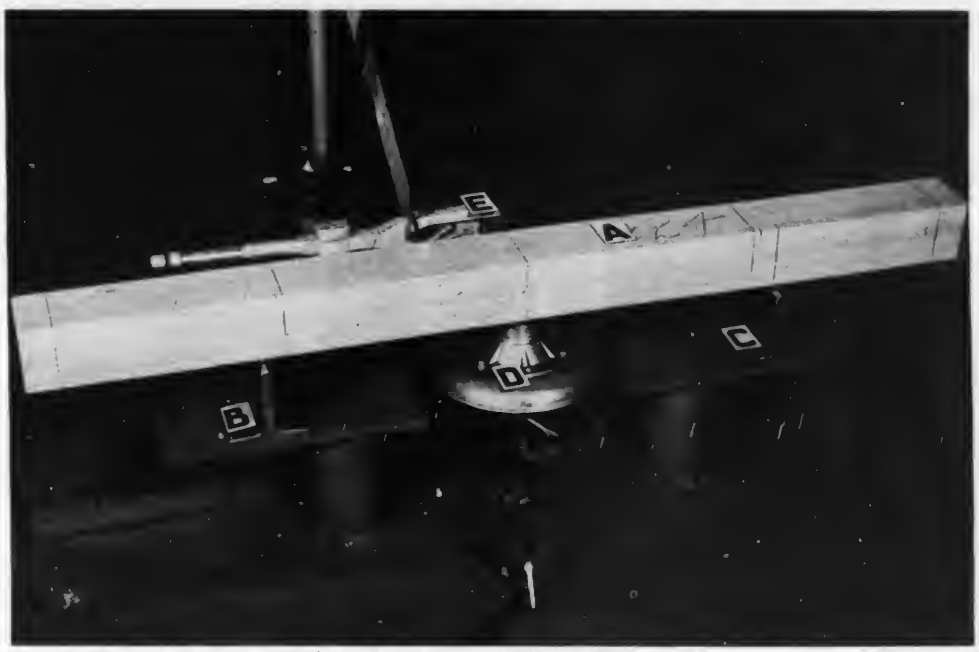

Fig. 3.—Transverse vibration of a beam. A is a laminated beam; B and C are supports at 0.224 L from each end; D is the dynamic vibrator; and E is the crystal pick-up.

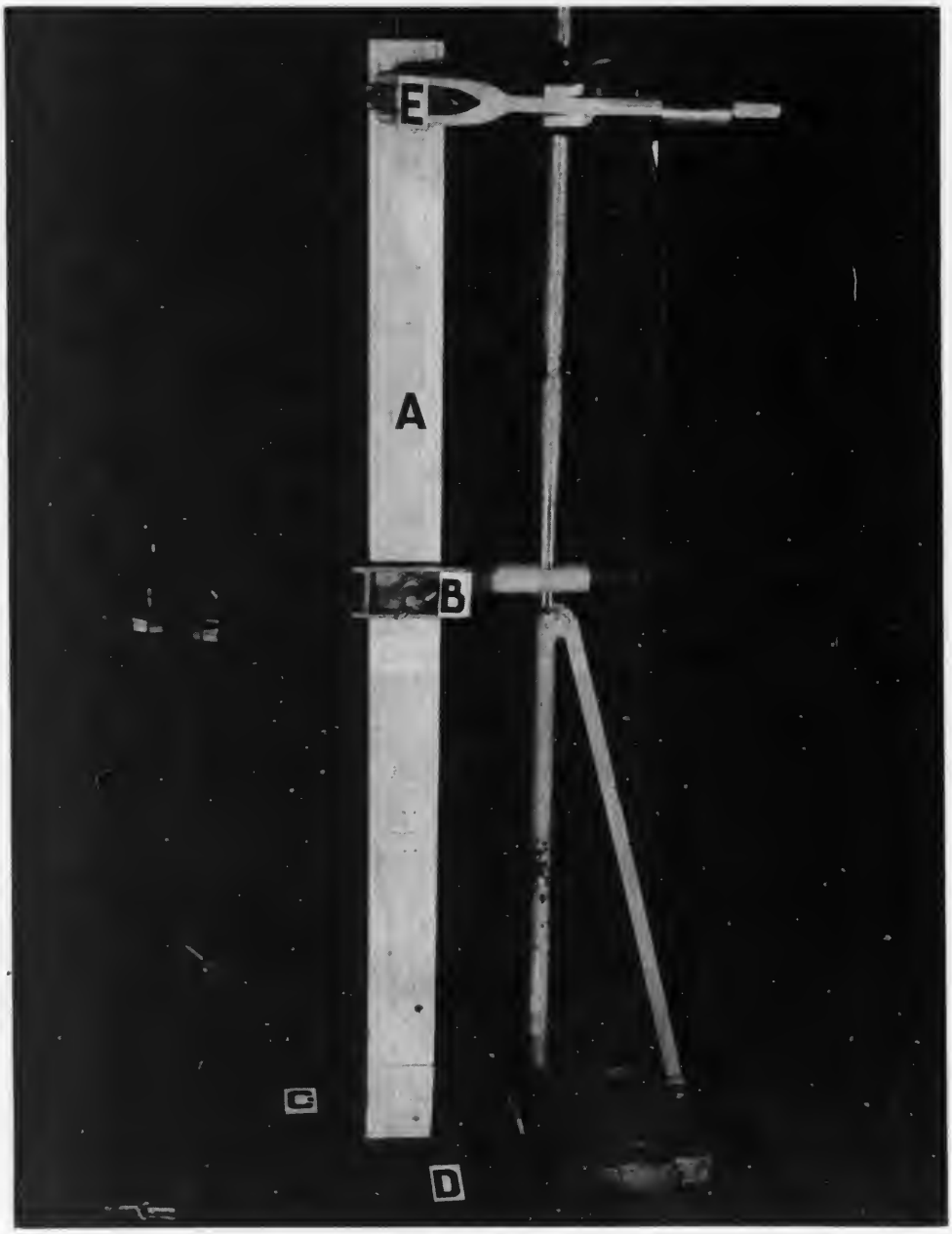

Fig. 4.—Longitudinal vibration of a beam. A is the test specimen; B is a central support; C the foil plate of the condenser exciter; D the base plate; and E is the crystal pick-up.

radio components is required to suppress spurious frequencies and to extend the frequency response of the circuits. For example, crystal pickups are not satisfactory for registering longitudinal vibrations from 2x2x8-inch columns since the resonant frequencies are greater than 10,000 c.p.s.

Care must be exercised in the design of supports, clamps, and jigs for holding the test item. The resonant frequencies of such systems should be outside of the range of resonant frequencies found for the production item.

Since the time that is required for a nondestructive test depends primarily on the speed of tuning for resonance, this test is rapid and holds forth much promise as another tool in the quality control of forest products.

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TECHNICAL SESSION V

Tuesday, June 27, 1950, 9:00 A. M.

General Subject: General Interest Session

Chairman: J. Alfred Hall, Director, Pacific Northwest Forest and Range Experiment Station, U. S. Forest Service, Portland, Oregon

Recorder: T. C. Spaulding, Professor, School of Forestry, Montana State University, Missoula, Montana (Chairman, Inland Empire Section, FPRS)

T. C. Spaulding, Dr. J. A. Hall,
E. S. Winlund.

FOREST PRODUCTS RESEARCH SOCIETY

Impregnation of Wood With Solid Metal Alloys

Frederick H. Vogel

Professor of Forest Utilization, Alabama Polytechnic Institute, Auburn, Alabama

A practical method is described for impregnating wood with solid metal alloys for use in bearings exposed to abrasive dust or submerged in water. The impregnated wood has sufficient reserve absorptive capacity to retain additional amounts of oils, greases or waxes for self lubrication. Hardness and abrasion resistance are significantly increased by metal impregnation, and the treated wood is markedly less hygroscopic, showing greatly improved dimensional stabilization. Gluing behavior is comparable to that of untreated wood except with the heaviest impregnations in a few species.

Introduction

METAL impregnated wood is not a new discovery, nor is the knowledge of it confined to the United States of America. The material has been, however, largely a laboratory curiosity here, and apparently only a few technicians have worked with it. Almost no published literature on the subject is to be found in reference libraries, although several German and Czechoslovakian factories are known to have made some use of metalized wood bearings prior to World War II.

Some work has been done on metal impregnation, metal-bath drying, and dimensional stabilization of wood veneer at the U. S. Forest Products Laboratory, and several patent disclosures have been made by Dr. A. J. Stamm of that laboratory, covering immersion of wood in molten alloys. The author worked on metal-impregnated, self-lubricated wooden bearings during the year 1947 while he was engaged as a research technician by the Timber Engineering Company of Washington, D. C., but no patent disclosures were made and there were no publications beyond a confidential report to the client.

While the conclusions drawn in this paper parallel similar ones made as a result of the confidential work done at the TECO laboratories, and while the techniques are similar, the results presented are based wholly on actual impregnations and tests made in the laboratories of the Alabama Polytechnic Institute Forestry Department, Auburn, Alabama.

Work on this project was directed toward the development of treating techniques, and toward the study of hardness and other physical properties. The scope of this paper includes only treating techniques, limited physical properties of impregnated wood, and the gluing behavior of the material.

Treating Factors

It is evident that the treatment of wood with molten metals is quite similar to treatment with any other liquid, whether water or oil, except that much higher temperatures are involved, special handling techniques must be employed to cope with the heated equipment, and only small blocks lend themselves to convenient treatment.

Species

Any species of wood may be treated with metal, but the retention and the penetration will vary considerably more between species than it will in the case of treatment with water or oil solutions. Explanation is readily apparent when metal-impregnated wood is viewed under magnification—the metal is found mostly in the lumens of the larger cells, and it appears to be absent from the cell wall structure, whereas aqueous solutions may be found both in the cell cavities and within the cell walls. Hence, retention of metals is primarily a function of cell lumen dimension and cell void proportion. Contrary to expectation, the ratio of retention to original wood specific gravity bears no correlative significance.

Sapwood Versus Heartwood

As in the case of conventional impregnations, the sapwood of every species treated was more receptive to impregnants than the heartwood of the same species. There is, however, a significantly higher retention of metal in heartwood, compared with sapwood, than is found in the case of water or oil treatments. This seems to be true because the major proportion

TABLE 1.—COMPARATIVE METAL RETENTION OF HEARTWOOD AND SAPWOOD OF SEVERAL SPECIES[1]

Species	Grams of metal[2] in 1½-inch cube
Sweet gum, sapwood (*Liquidambar styraciflua* L.)	84.38
Sweet gum, heartwood	24.90
American ash, sapwood (*Fraxinus americana* L.)	36.08
American ash, heartwood	19.45
Laurel oak, sapwood (*Quercuslaurifolia* Michx.)	23.00
Laurel oak, heartwood	11.90
Overcup oak, sapwood (*Quercus lyrata* Walt.)	46.12
Overcup oak, heartwood	9.80
Average all sapwood	47.39
Average all heartwood	16.51

[1]Based on average of five specimens of each species, sapwood and heartwood. 10 minutes preheating; 3 minutes at 200°C. at 50 psi.
[2]Cerrobend alloy, made by the Cerro de Pasco Copper Co.

of the penetration of molten metals occurs longitudinally in the larger cells and vessels which are relatively more easily penetrated, even when partially plugged with tyloses. In some species such as southern cypress there was comparatively little impregnation of either heartwood or sapwood by metals, whereas in other species such as sweet gum the sapwood was easily and very heavily treated while the heartwood was resistant.

Temperature

Metal impregnation may be accomplished at any temperature between two roughly defined limits: the lower limit is the melting (or solidifying) point of the particular metal alloy employed, and the upper point is the charring temperature of the particular species of wood under test. It is well known that eutectic alloys of lead, tin, cadmium and bismuth may be made to melt at temperatures well below the boiling point of water, and that any other melting point as high as the maximum that may be sustained by wood may be achieved by increasing the percentage of lead or tin in the alloy. Wood will sustain a higher temperature when immersed in molten metal than it will when heated in the atmosphere. If it be desired to study the gross inner structure of wood by means of metal cell casts, this method lends itself well to that end. The bath temperature may then be raised momentarily above the carbonization point, whereupon the final products will be impregnated charcoal and the usual distillates of wood. Immersion of the block below the surface of the molten alloy prevents complete oxidation of the charcoal during the interim of temperature and pressure when the wood undergoes an exothermic reaction. It is hardly necessary to state that the alloy bath should be reduced in temperature before the charcoal is extracted, and the charcoal must then be cooled below the solidifying temperature of the alloy before the charcoal is crumbled away from the casts.

The Forest Products Laboratory has worked on the ignition temperatures of various species of wood, and has found the answer to vary according to the exposure time. Concisely stated, any species of wood may be destroyed by a very high temperature for a short time, or by a comparatively low temperature over a long period of time. Light-weight species prove more susceptible to heat damage than species of high specific gravity, but that difference gradually disappears at temperatures over 300° C.

For the work covered by this paper, a treating temperature of 200° C. was employed, and the treating bath was allowed to cool to 180° C. during the time under pressure.

Pressure

Pressures as low as 50 psi. result in excellent penetrations and retentions in small wood blocks of many species, and that arbitrary pressure has been employed for all the work reported in this paper. The author has carried out parallel work at pressures as high as 200 psi., and it is evident that various species-groups require different pressures for good impregnation. Thus, species such as the gums treat well at low pressures, and nothing is to be gained by higher pressure treatment. On the other hand, Douglas fir treats well only at higher pressures, and cypress resists treatment to the point of collapse.

TABLE 2.—HARDNESS OF UNTREATED, METAL-BATH-TREATED, AND METAL-IMPREGNATED WOOD[1]

Species	Untreated			Metal-bath-treated[2]			Metal-impregnated[3]		
	End	Rad.	Tang.	End	Rad.	Tang.	End	Rad.	Tang.
Sweet gum, sapwood *Liquidambar styraciflua* L.	1077	783	862	1280	700	975	1497	1180	1287
Tupelo gum, sapwood *Nyssa aquatica* L.	1180	867	940	1450	812	1017	1550	1200	1400
American ash, sapwood *Fraxinus americana* L.	855	570	477	842	551	632	1550	1000	1053
Cypress, heartwood *Taxodium distichum* (L.) Rich.	350	197	195	575	375	390	677	370	300
Average	865	604	618	1037	609	753	1318	937	1010

[1]Based on average of five specimens of each species. Standard ball indentation.
[2]10 minutes at 210°C.
[3]10 minutes preheating; 3 minutes at 200°C. at 50 psi.

Time

In small, preheated wood blocks, maximum retention is attained within one to five minutes from the time of application of pressure. If the blocks are not adequately preheated, however, it may require ten minutes or more additional treating time. For the work included in this paper, a standard time was adopted of ten minutes heat conditioning followed by three minutes under pressure.

Preheating

It is recommended that all wood to be metal-treated should first be dried to a low moisture content, then immersed in an open bath of molten metal slightly above the treating temperature until the wood is heated throughout. During this preheating period, the molten metal will "boil" vigorously as the expanding air and escaping steam force their way out of the wood. It is quite probable that high internal pressures are built up within the wood at the first of this period because the bubbles escape violently, and some species of wood such as the oaks may bulge conspicuously or even explode. Treatment is easy after about ten minutes of heat conditioning at 210° C.

Subsequent Treatment With Other Impregnants

Metal impregnated wood is found to retain some capacity for absorption of water or oil solutions even after the heaviest retentions of metal, especially if the subsequent impregnation is made at elevated pressures. Hence, self-lubricated bearing blocks can be made of wood by first impregnating with a suitable alloy, then with whatever lubricant is desired. Oils, greases and waxes, separately and in mixture, have all been successfully impregnated into metal-treated wood by the author.

Gluing Behavior of Metal-Treated Wood

A study is currently being carried out at Auburn to determine whether metal-impregnated wood behaves in gluing as wood or as metal. Incomplete results of the study, conducted to date with only one adhesive and primer show that it is difficult to make a single generalization.

Most ordinary specimens glued as well after treatment as before, with Perkins Aircraft Joint (casein) glue, except in those cases in which the actual gluing surface was heavily metalized. Under some treating procedures, the surfaces of the treated wood appeared almost normal, even when the interior was heavily impregnated; in those cases the blocks glued as well as untreated wood. If sanded down to expose the heavily impregnated zone, however, it was found advisable to prime the metallic surface with Perkins Tufcol Primer before gluing.

After some experience, the operator should be able to judge from the appearance of the gluing faces whether or not they need be primed to make a satisfactory joint. Some adhesives which will be tested may behave in a different manner, and the generalizations which are presented above should be applied for the present only to Perkins Aircraft Joint Glue (casein) and Perkins Tufcol Primer.

Conclusions

Hardness is increased significantly in the softer and lighter species. Dimensional stability is significantly increased. Heat conductivity and electrical conductivity are greatly increased. Weight is increased as much as ten-fold in the sapwood of some species. Permeability to subsequent impregnants is greatly reduced but not lost. Gluing behavior is in many cases comparable to that of untreated wood.

Discussion

Mr. E. D. Marshall (Forest Products Department, Texas Forest Service): Is there a difference in impregnation of summerwood versus springwood?

Mr. Vogel: Yes, there is a difference, but it does not always follow expected patterns. Difference in impregnation of summerwood and springwood in the same species appears to be related to the size of cellular cavities more than to other factors. Heavy resin content in pine summerwood inhibits penetration, as do the very small lumen cavities. In the ring porous hardwoods, such as the oaks, most of the penetration also occurs longitudinally in the springwood.

Mr. Marshall: I have always had an interest in petrified wood. Have you ever tried impregnations of wood with silicon dioxide? If not, what is your opinion on the possibilities of such impregnations?

Mr. Vogel: I have had no experience with the silicon compounds, but I think there may be real possibilities for a limited field of hardened wood products.

Mr. J. Alfred Hall (Pacific Northwest Forest Experiment Station): Is the structure of the metal continuous and is plastic flow a problem?

Mr. Vogel: No, the metal structure is not continuous in metal-impregnated wood. Metal apparently fills only the cell lumens in the larger cells in many species. In some species, such as the gums, the metal structure seems to form what approximates an electrically connected lace network, but it can hardly be considered structurally a unit. At the connecting pits, the metal is either "pinched off" or is exceedingly fine.

Plastic flow has not been a problem in the work that has been done to date.

Mr. Lincoln A. Mueller (Forest Utilization Service, Northern Rocky Mountain Forest Station): You mentioned that you obtained low retention in the oaks; is that true in both white and black oak groups?

Mr. Vogel: Retention was relatively low in all the oaks with which I have worked, including several white oaks, several red oaks, and heartwood and sapwood of each.

I do not yet know why the metal freely enters very small cells in the gums, but enters only much larger vessels in sap oak.

Mr. F. H. Kaufert (Division of Forestry, University of Minnesota): Did you find much in the German wood technology literature on metal impregnated wood? Kollmann in his "Technologie des Holzes" does include some information on this.

Mr. Vogel: I reviewed the German literature and found only a few general references to metal impregnated wood. The material in Kollmann's book contains most of this.

FOREST PRODUCTS RESEARCH SOCIETY

How to Boost RF Gluing Production Edge-Gluing and End-Gluing

Ed. S. Winlund
Electronics Engineer, Westinghouse Electric Corporation, Seattle, Washington

Although the cost reductions and quality improvements obtained with RF edge-gluing are now very well established, there are a number of users whose results fall short of those known to be obtainable.
Rather than further proclaim the clear advantages of RF-gluing, this is a deliberately critical point-by-point analysis of factors affe ting results, with recommendations for the proper solution of each.
Only a few of these critical factors are likely to be effective at any one installation. It is seldom difficult to identify them from their symptoms, and to apply corrective measures to get optimum results.

Introduction

AS THE title implies, this report is intended primarily for the superintendent of an existing or contemplated RF edge-gluing or end-gluing installation, to help him obtain more production, better quality, lower fall-down, and lower cost of operation.

All comments refer to *edge-gluing* unless end-gluing is specifically mentioned. Edge-gluing is defined as the bonding together of the edges (narrowest sides) of boards to make wider boards or panels, as contrasted to lamination wherein the faces (widest sides) are bonded together. End-gluing may be used to (a) improve the grade of otherwise knotty lumber, by cutting out knots and re-joining the pieces, (b) to join the ends of moulding or lumber to make long standard stock or special lengths, or (c) to join the ends sufficiently for handling prior to edge-gluing to make panels.

In order to illustrate the effects of improper stock preparation, gluespread, etc. in many of the figures in this paper, it is assumed that the pressload is of such size and shape that 20 kilowatts will deliver 1000 volts to the electrodes, heating the glue to 180° F. in 20 seconds time, at which temperature it sets. This relatively large load would be rather typical in the softwood lumber country.

The furniture industry, on the other hand, generally operates with smaller pressloads, where 10 kilowatts is adequate. The illustrations are still directly applicable by dividing all power figures by two; that is 10 kw. would deliver 1000 volts, raising the glue to 180° F. in 20 seconds.

Stock Preparation

In our experience, the most important single thing that a new user of high frequency edge-gluing must understand is that the wood edges and faces must be flat and square with each other, considerably more so than was permissible with clamp carriers. The edges must have virtually wood-to-wood contact over their entire area before glue is applied. This is obtained as follows:

Flatness

The stock must be flat before jointing or ripping the edges. A warp or twist will usually prevent a steady reference plane, as in Fig. 1, making the edge square perhaps at one point, but not elsewhere on its length. Chain-feed low pressure holding devices, however, will establish a sufficiently steady plane to handle softwoods with only a slight warp or twist.

Edge Condition

The edges must be straight as they come out of the jointer or ripsaw. This means that the stock must be held very firmly in transit and that the holding mechanism must be straight.

Feed-through grippers with excessively worn tracks and bearings can easily result in a poor joint. Excessively worn gripper teeth and roller knurling will likewise let the stock slip minutely in transit, resulting in a "hollow" or "high" joint. Cumulative hollow joints in a panel reduce or remove pressure or leave an opening at the center, as in Fig. 2, which shows estimated pressures. Hollow joints must be especially avoided in long panels and/or in hardwoods, because even fluid edge pressure has less chance to make up the deficiency.

The edges must be square as they leave the jointer. This is seldom a problem, occurring only when the jointer is adjusted out of square, or if the stock is not flat. As in Fig. 3, off-square edges will (a) obviously put excessive

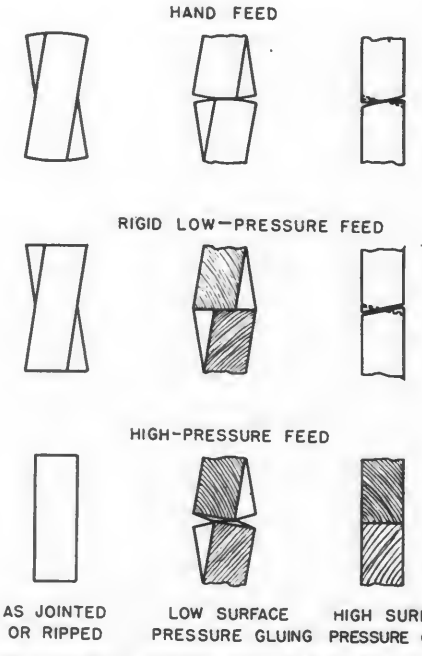

Fig. 1.—Feed and gluing pressure as related to joint contact for warped stock.

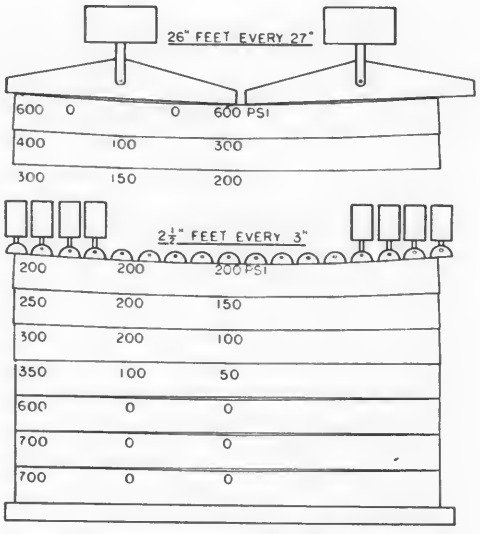

Fig. 2.—How hollow edges affect glue pressure.

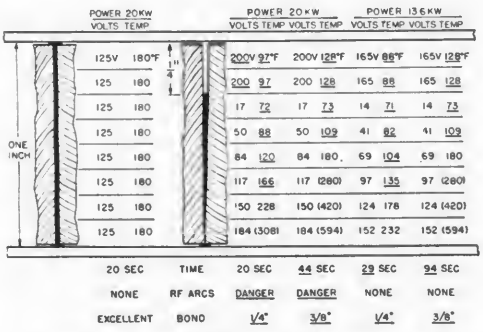
POWER 20 KW VOLTS TEMP
POWER 20 KW VOLTS TEMP VOLTS TEMP
POWER 13.6 KW VOLTS TEMP VOLTS TEMP
ONE INCH
20 SEC NONE EXCELLENT
TIME RF ARCS BOND
20 SEC DANGER 1/4"
44 SEC DANGER 3/8"
29 SEC NONE 1/4"
94 SEC NONE 3/8"

Fig. 3.—Electrical effects of off-square edges.

pressure along one side of the edge and insufficient pressure or even an opening along the other side, (b) prevent uniform glue distribution, and (c) may crush wood fiber. But more important are the illustrated electrical effects which unnecessarily prolong RF heating time. In the example of Fig. 3, it is assumed that the off-square edge permits only ¾-inch-wide glue coverage on the one-inch edge, leaving ¼ inch without glue. The columns of figures show the voltages and consequent temperatures obtained in each ⅛-inch-thick layer of wood, at the left of a good joint, at the right of the off-square joint.

With 1000 volts between electrodes, a good joint divides this evenly into 125 volts across each ⅛ inch of thickness, because the glue is a uniformly good conductor. The result is that every ⅛ inch is heated at the same rate as every other ⅛ inch, and they all arrive at 180° F. (assumed the setting temperature) in 20 seconds.

On the other hand, the off-square joint has ¼ inch without glue, the remaining wood being a relatively poor conductor (i.e., high resistance) as a result of which there is *more* voltage drop than there should be across each of the top two ⅛-inch sections causing danger of an arc. Likewise, the variable thickness of glue line results in very little temperature rise at its thickest point, and excessive rise at its thinnest. The result is that only about ¼ inch near the thin glue-line side gets bonded.

If the danger of arc is ignored (power kept at 20 kw.) and time is increased to 44 seconds, a little more glue is set. If power is reduced to 13.6 kw. to avoid the danger of arcs, the corresponding times are 29 and 94 seconds.

The overall result is that this one bad joint in a pressload of otherwise good ones (a) will not set up itself, and (b) may require increas-

ing the RF heating time for the whole press-load from 20 to 29 seconds just to get away from the possibility of an arc. An arc would not be *probable* at 20 seconds (20 kw.); it is just that the safety factor would be virtually gone.

Thickness

The stock thickness should be uniform. This also is seldom a problem, as no difficulty is generally encountered for total tolerances of $\frac{1}{16}$ inch. The effect of greater differences of thickness is to introduce an excessive series gap in the conducting glue line between electrodes, which, like off-square edges, lowers the voltage gradient in the glue and hence the attained temperature, as in Fig. 4. If high tolerances

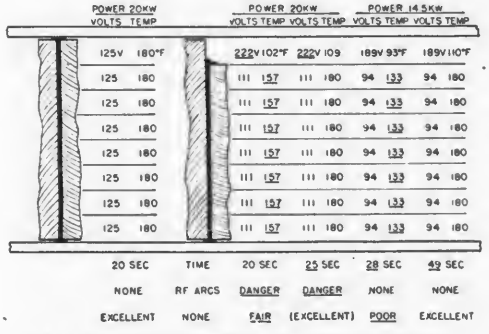

Fig. 4.—Electrical effects of uneven thickness.

cannot be avoided, a satisfactory joint may be obtained by lowering RF voltage to avoid arcs and/or correspondingly lengthening the heating time, so that the proper temperature is obtained in spite of the lower RF voltage gradient. Differences of ¼ inch have been handled successfully in this manner.

For *end-gluing,* the best type of splice depends upon the strength demanded by the application. In Fig. 5, a conventional 12:1 scarf is shown, which has very great strength; however, it wastes considerable wood and sometimes the feather edge is difficult to handle. Much less wasteful is the finger joint, which gives very good strength but requires more complex cutters and higher precision. The zee joint requires simpler cutters and less precision, but generally has strength adequate only for normal handling prior to subsequent edge-gluing. Although with end-gluing a lower

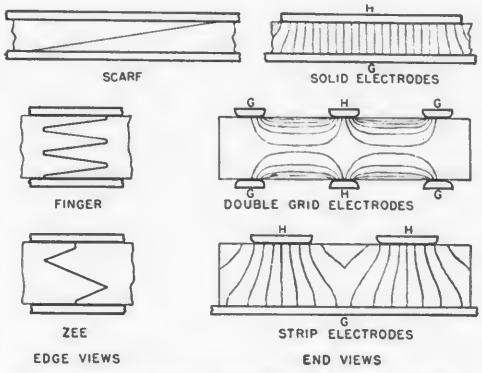

Fig. 5.—End-gluing and electrode arrangement.

strength joint may often be tolerated, it is inherently more difficult to bond end grain. The scarf requires merely flatness, particularly if any displacement of the feather edges will later be machined off. The fingerand zee joints require high precision and sharp cutters, since the two ends "bottom" into each other, and wood-to-wood contact is needed on all meeting surfaces. The stock must be held absolutely flat while cutting the ends, must be cut in very straight line across the stock, and square with the reference edges.

The electrical situation is not the same as for edge-gluing because the glue current path is always considerably longer (higher resistance) than the wood thickness. This and other field distortion effects cause a much greater part of the power to go into wood, less into glue, thus provide lower effective efficiency, particularly for finger and scarf joints. One might say that the efficiency of end-gluing is somewhere between that of edge-gluing and lamination, where glue lines are generally parallel to the electrodes.

Accordingly, stock thickness tolerance may have less effect than for edge-gluing, because power is going primarily into wood, and the effect of small series air gaps is not so great.

Moisture Content

Moisture content must be controlled. There is evidence that the strongest bond occurs at 8 to 10 percent moisture. Above 10 percent moisture content there is said to be a tendency for the glue resin (but not the water in which it is dissolved) to migrate into the wood.

The resultant deficiency of resin at the glue line can of course impair strength. At 15 percent moisture poor glue bonds result. Below 6 to 8 percent there seems to be a gradual reduction of specific adhesion, possibly because the drier wood sucks water out of the glue, also resulting in impaired strength. It is especially helpful to keep moisture content up with staggered electrodes because of the increased moisture migration time available in the areas deliberately uncooked. Urea glues are more sensitive than resorcinols in this respect.

For most RF gluing applications, however, the bond strength is more than adequate even though reduced by off-optimum moisture content. Thus some other factors are generally controlling.

The usual edge-gluing operation places both wood and glue lines between the electrodes. When the available RF power develops a certain voltage across these electrodes, only about half the power goes to heat the glue lines and half goes to heat the wood. (While the temperature rise in the wood may be but a small fraction of that in the glue lines, it must be remembered that a lot more wood than glue line is heated those few degrees, thus the substantial power loss in the wood). It is like paralleling one 100-watt light bulb (the glue line) and say 10 small 10-watt bulbs (the wood), all across the 115-volt line; both groups draw the same power, but the 100-watt bulb is much hotter to the hand.

The electrical "conductivity" (actually "loss factor") of the wood, and therefore the power loss in it, increases more or less proportionally to moisture content, except that a minimum is reached in the neighborhood of 3 to 5 percent moisture content below which a further reduction will not significantly reduce power loss.

As shown in Table 1, starting with optimum content of say 6 percent, half the power goes into glue and half into wood. Doubling wood moisture content to 12 percent causes one-third of the power to go into glue and two-thirds into wood. Since the glue power has been dropped from half to a third, the same time (20 seconds) gives a poor joint, or an increase to 30 seconds gives a good joint—not excellent, because glue migration is likely.

Halving the moisture content conversely permits a good bond in three-fourths of the time, or 15 seconds, but the rising voltage at 20 kw. causes danger of an arc. Therefore dropping the power to 15 kw. gives a good joint in 20 seconds without danger of an arc.

Accordingly a reduction (except below 3 to 5 percent) of moisture content will always reduce the power lost in unnecessarily heating wood, thus leaving more of the available RF power for the glue lines. This permits a shorter RF heating time and/or the use of less power.

Of course the primary reason for reducing moisture content has always been to provide dimensional stability and freedom from warping throughout the life of the product. In the 5 to 15 percent range, the *uniformity* of moisture content is very much better with a 5 percent average than with 15 percent, so that eventual stresses in and consequent warping of a glued-up panel is much less likely with the lower moisture content.

All of these effects result in consensus that moisture content ought to be between 5 and

TABLE 1.—MOISTURE CONTENT AND INITIAL TEMPERATURE

Moisture Content	Time		RF			Wood Temp.	Glue Line	
	Seconds	Excess	Power	Volts	Arcs		Temp.	Bond
Halved	15 sec.	----------	20 KW	1154 V	Danger	75°F	180°F	(Good)
	20	0	20	1154	Danger	77	217	(Good)
	20	0	15	1000	None	75	180	(Good)
Optimum	20	0	20	1000	None	80	180	Excellent
Doubled	20	0	20	816	None	83	143	Poor
	30	50 percent	20	816	None	90	180	Good
Initial Temperature								
20°F Low	24 sec.	20 percent	20 KW	1000 V	None	62°F	180°F	Excellent
	20	0	20	1000	None	60	160	Fair
Optimum	20	0	20	1000	None	80	180	Excellent
20°F High	20	0	20	1000	None	100	200	Excellent
	16	Faster	20	1000	None	98	180	Excellent

11 percent for RF edge-gluing, and generally the lower the better within this range.

Lower moisture contents can be tolerated with solid electrodes, but moisture migration from unpolymerized areas makes lower moisture contents inadvisable for staggered electrodes.

It is very important that edge-gluing be done within at most 4 to 8 hours after the stock is jointed or ripped; otherwise the flow of moisture into or out of the ends and edges will very likely warp the stock.

For end-gluing, although the effect of moisture content upon end-grain glue adhesion is not known to the writer, the desirability of low moisture content from an efficiency standpoint is even greater than for edge-gluing, because here more power goes into wood. Probably it should be 5 to 8 percent, preferably 5 percent.

Stock Temperature

Stock temperature should be controlled. Initial glue-line temperature, and therefore stock temperature which directly affects it, is important in two respects. First, the higher the temperature the lower will be the glue-line temperature *rise* required, and therefore the shorter the RF heating time, as shown in Table 1.

Secondly, warmer stock is especially advantageous for staggered electrode presses, to help the deliberately unpolymerized areas to polymerize before excessive moisture or resin migration can take place.

Initial glue-line temperature is determined by both stock and glue temperature, to about the same degree, and by press room temperature to a lesser degree if the open assembly time is properly short. It should be in the neighborhood of 70 to 80° F., the higher the better so long as the glue pot is kept cool enough and spread, layup, and closure are fast enough to obtain full pressure before polymerization starts. Trouble with precuring is likely to be encountered above 80° F.

One method of obtaining high initial glue-line temperature is to route the flow of stock through heated rooms or tunnels for a few hours prior to spreading, and to maintain the press room at 70 to 80° F. Another is to use suitable means to bring the edge temperatures up immediately prior to spreading, but this is more difficult than simply keeping a room or two at proper temperature.

Aside from shortening the RF heating time and assuring ultimately complete polymerization, keeping a room or two warm also helps to obtain or keep the proper low moisture content and to keep the oil of hydraulically operated presses warm for faster reload action. Of course the warmer the press room is kept, the more desirable is a cooler on the glue spreader to maintain proper pot life.

The effect of initial stock temperature on end-gluing is greater than for edge-gluing because more power goes to heat wood. The wood should be at least 70° F. and preferably 80° F.

Species

Species affects heating time. The effect is shown in Table 2 and is similar but of often greater magnitude, than that due to variation in moisture content. For example, the denser soft-

TABLE 2.—WOOD DENSITY AND GLUE CONDUCTIVITY

Wood Density	Time		RF			Wood Temp.	Glue Line	
	Seconds	Excess	Power	Volts	Arcs		Temp.	Bond
Halved	15 Sec.	----------	20 kw.	1154 V	Danger	75°F	180°F	(Excellent)
	20	0	20	1154	Danger	77	217	(Excellent)
	20	0	15	1000	None	75	180	Excellent
Optimum	20	0	20	1000	None	80	180	Excellent
Doubled	20	0	20	816	None	83	143	Poor
	30	50 percent	20	816	None	90	180	Excellent
Glue Conductivity								
Halved	40 Sec.	100 percent	15 kw.	1000 V	None	90°F	180°F	Excellent
	30	50	20	1154	Danger	90	180	(Excellent)
	20	0	20	1154	Danger	83	143	Poor
Optimum	20	0	20	1000	None	80	180	Excellent
Doubled	20	0	20	816	Arc*	77	217	(Excellent)
	15	----------	20	816	Arc*	75	180	(Excellent)

*Due to salt in glue.

woods such as Douglas fir and ponderosa pine will require a longer heating cycle than Sitka spruce or redwood because more power is consumed heating wood, less being available for the glue lines. Hardwoods not only require more power and/or time because of the greater density (more weight of wood to heat), but also because a stronger grip is needed to hold the boards together against the greater board stiffness.

The effect of species upon end-gluing heating time is the same as for edge-gluing, except magnified by the greater amount of power going into wood.

Stock Width

Wide stock reduces gluing costs, up to a point. Obviously it (a) requires fewer glue lines per board foot, therefore permits a higher production rate, (b) requires less glue, (c) requires less layup handling, and (d) requires less machining time ahead of layup. However the problems of warpage and hollow edges multiply very rapidly with the width of relatively long stock, especially hardwoods.

To avoid the latter difficulty, most of the furniture industry has found it expedient to rip wide hardwood stock to 3½-inch width or less, and the watcher reverses alternate pieces at layup to avoid warping of the final panel. Thus the maximum practical stock width is usually determined by trial and error.

Glue

Modern resin glues, properly used, have greater strength than the woods they bond together. To obtain adequate strength for the application at hand, there are ranges of conditions within which they must be used. These conditions are more strict than those under which animal and other glues may be used with conventional clamp carriers.

Nearly all of the manufacturers of resin glues maintain regional technicians, usually the salesmen themselves, who are experts in the proper use of their company's products, and who are more than willing to spend adequate time at the production facilities to assure proper conditions. Most of these men have very considerable experience with RF gluing, and have picked up valuable experience well beyond the mere use of the glue itself.

We cannot emphasize too strongly the value of asking one of these men to help with RF gluing problems. They don't always agree with each other, yet there is a broad area of general agreement between them and between electronic representatives, which for edge-gluing is listed below. End-gluing can usually be done with the same conventional resin types, but often the glue manufacturers can recommend special formulations especially adapted to the end-grain application. They should be consulted.

Resin Glues

Resin glues cannot compensate for poor stock preparation. Resin glues provide a superior bond, and can be polymerized or set very much faster than others, but they do not have good strength as fillers. That is, if an off-square or hollow edge provides an unduly wide gap between boards, and the attempt is made to fill the gap with a heavier spread, the resultant joint will be weak. Some resin glues, such as resorcinols and "gap-filling resins" are reported to have better filler strength than others, but the difference does not permit significant relaxation of the proper stock preparation requirements.

Catalyst Proportions

Catalyst proportions must be tried on the job. The proportion of catalyst or "hardener" must be chosen with care, starting with the manufacturer's standard recommendation. It ranges from 10 to 20 percent, depending not only upon the resin and catalyst chemical formulation, but also upon a number of conditions at the press. The electrode arrangement (staggered vs. solid platen vs. airgap, if any), size of press, RF power and frequency all affect interelectrode voltage, which, considered with stock thickness, determine maximum voltage gradient.

Some glues are more conductive than others, thus heat faster. If the catalyst contains, as it usually does, a conducting agent (sometimes table salt), more catalyst always gives higher efficiency (a higher percentage of power goes into glue, rather than heating wood) but the voltage gradient determines a maximum amount of catalyst that may be used without danger of arcs. The procedure generally is

either to increase gradually the amount of catalyst until arcs occur too frequently, and then drop back to a lower amount of catalyst, or to reduce catalyst until pot-life is too short. This trial and error method is usually conducted by the glue manufacturer's representative, under production conditions. The effect of varying glue conductivity is shown in Table 2.

Different glue formulations, even among glues of one type (say urea) or one manufacturer, have different percentages of electrolyte, thus require different additions of salt for optimum operation, introduced by the glue manufacturer. Salt doctoring by plant personnel is not recommended.

Pot life generally decreases as the proportion of catalyst is reduced, but not always. There is always some percentage of catalyst, which may or may not be within the 10 to 20 percent range, below which a further decrease will increase the pot life. Obviously zero percent catalyst gives a very long pot life.

Glue Spread

Glue spread must be controlled. Glue spreaders are supposed to spread the glue so that there will be full coverage of the edge and uniform transfer to the opposing edge, under pressure, and a little squeezeout. The resulting film should be uniform if the edges are square and straight. Some squeezeout is desirable (a) to assure adequate spread, and (b) to help make contact with the electrodes. A series glue path between electrodes and the glue line doesn't cause arcs; it discourages them!

Either smooth or narrow grooved (say $\frac{1}{16}$-inch wide "V") rollers with smooth or no doctor bars, or smooth rollers with narrow-toothed doctor bars, seem to do very nicely. Rubber seems to provide no advantage over metal rollers, and is often tougher to clean and costlier to maintain. Wide-groove rollers or other larger-pattern roller surfaces often have a tendency to leave little unspread areas, even under pressure, especially when the glue gets thick, but they are sometimes helpful for slightly warped stock. Of course warped stock cannot be expected to permit a very good bond in any event. In some operations a rubber hold-down roll is very helpful.

Adequate glue spread generally runs 25 to 45 pounds of mixed glue per 1000 square feet of single glue-line area. Edge gluing may require 30 pounds for really smooth jointer edges to 40 pounds for rather rough ripped edges, or an average of 35 pounds for an average jointer edge or a very good ripped edge. Resorcinol glues are more alkaline than ureas, tend to penetrate more, and thus may require 5 to 10 percent more spread than the above figures.

If the glue spread is insufficient but uniform, the normal amount of penetration into the wood may leave too little for the glue line itself, resulting in a "starved" joint. Also since the deficiency of glue also provides a higher resistance glue current path between electrodes, less RF current flows to heat the glue, so it does not reach proper setting temperature and is usually damp to the touch when broken open.

If the glue spread does not extend across the piece (due to insufficient spread and/or off-square edges), the deficient area, being wood, is an undesired higher resistance current path in series with the remaining glue line, which identically prevents the glue from reaching proper temperature, as outlined just above. In this instance, however, there is an added danger of arcing due to the high voltage gradient occurring in the unspread portion of the glue line, as shown in Fig. 6.

The cumulative effect of insufficient spread, even if only on one or two edges of a press-load, is therefore to require a longer RF heating cycle just to get a bond on those few edges, or to avoid arcs.

Excessive spread obviously increases glue cost, takes a longer RF heating time to heat the additional glue, and increases cleaning costs due to excessive squeezeout. It should therefore

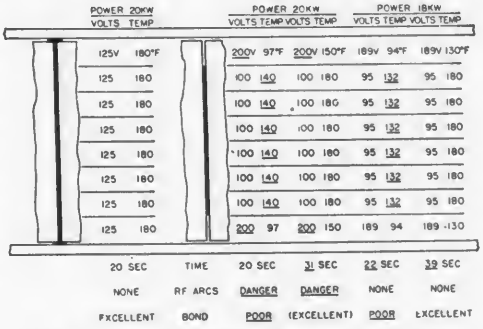

Fig. 6.—Electrical effects of poor spread—poor spread on one board.

be apparent that there is definitely an optimum glue spread, and that use of either less or more than that will increase RF heating time and general costs of the operation. Any unavoidable variation should be on the side of heavier spread, however.

The above comments apply as well to end-gluing, but glue spread must be especially well controlled because of the lack of opportunity for squeezeout.

The Press

Properly designed edge-gluing presses (a) facilitate stock layup with minimum manual effort and time, (b) hold the completed layup flat while (c) sufficient edge pressure is applied to obtain contact between all edges, (d) apply RF voltage across the glue line for a sufficient time to set good joints, (e) eject the glued panels while accepting fresh layups, all as automatically as practicable. The great majority of RF presses in use today do this on a batch basis; i.e., the stock comes to rest while RF is applied. Two or three makes have continuous layup tables (nevertheless batch heating) which save a number of seconds otherwise required for return of the feed ram. A few makes are truly continuous, RF being applied with stock in motion, under pressure, which considerably lowers the RF generator power requirement, and in some situations eliminates the need for board matching. But common to all types are these requirements:

High edge pressure is essential. No other design feature of a press has more bearing on the results. A not unreasonable rule is that the system should be capable of crushing wood, which leaves some reserve when the pressure is backed off for actual use.

Perfectly square and straight edges, with a uniform thin glue spread, of course require little or no pressure for an excellent bond. But the fact is that despite proper preparation of stock, it still is never perfectly square and straight, and only pressure can make up the deficiencies.

If the press is to be used for hardwoods, this means edge-pressures of the order of 250 to 350 psi. are desirable, and of course they are limited by the maximum thickness to be glued. Very wide and long hardwood boards (say 12 inches by 8 feet) may require up to 550 psi. For softwoods, pressures of 150 to 250 psi. give excellent results. Good results are sometimes obtained with pressures as low as 75 psi., but in our experience this does not permit permanently dependable operation, except with soft, low-density species.

Uniform edge pressure is important. Some means must be provided to exert uniform edge pressure regardless of variable length and width of stock, slightly hollow edges and wedges. Actual fluid pressure is a theoretical ideal, but difficult to apply. Near-fluid pressure can be obtained using a number of close-spaced and relatively short pressure feet each individually or "double tree" activated by hydraulic or pneumatic cylinders or springs, or by the use of face friction restriction against continuous broadside stock flow.

Presses for end-gluing must of course hold the pieces in proper alignment while RF is applied, but should require less end-pressure than edge-gluing because of the direction of the glue lines. In continuous presses it is particularly important that there be absolutely *no relative movement* between the two pieces being joined, though they may be travelling, while the RF is on. Experience has shown that the slightest relative movement after the glue has begun to polymerize will seriously reduce joint strength.

Layup tables should have maximum time availability. Layup tables are located just ahead of the press, with the glue spreader "wet" conveyor usually running conveniently a foot or two above them. Most batch presses have a feed ram at the end of the layup table, which, as soon as all boards have been laid in place on the table, shoves the whole layup into the press, and immediately returns to the head end to permit the next layup while RF is on. The table unavailable time (while feed ram is in motion) is usually the order of 5 to 8 seconds, compared to a 30- to 50-second total cycle. Batch presses using continuous feed tables instead of a feed ram cut the unavailable time to 3 to 7 seconds. Fully continuous presses of course cut the unavailable time to zero.

Reload Factor

Press reload time must be minimized. Reload time is defined as the total time between RF heats. The total press cycle time is the sum of RF heat and reload times, and divided into 3600 seconds gives the production in press loads per hour of steady operation. Most batch presses have reload times of the order of 8 to 20 seconds. Only a small part of this (the lay-up table unavailability time of 3 to 8 seconds) is actually lost time for the operators, but the reload time is idle time for the generator and press. Therefore reduction of the proportion of reload time to total cycle increases the production capabilities of a given generator and press size.

Care of Equipment

Cleaning and maintenance must be considered. Most edge-gluing installations seem to get about seven hours of steady production out of an 8 hour shift. The remaining hour (8:00 A. M., rest periods, 4:00 P. M.) is used for cleaning glue off the glue spreader conveyor, mixing glue, handling falldown due to bad stock, etc., and miscellaneous timeouts for the operators. About half a crew can handle cleaning and mixing in this time.

Cleaning of the press itself seldom presents a problem in batch presses. In ram-feed types there is constant scraping of the electrodes by the lumber, and what is left at the end of the shift dries to a film which is easily peeled off in a few minutes when operation is resumed.

Unless unusual provision is made to dry squeezeout at the press, electronic presses generally leave a small amount of wet surface glue on each glued panel, because the relatively cool electrodes conduct away any surface heat developed in the glue by the RF, before its temperature can rise very far. The electrodes of thermally-insulated staggered-electrode presses, however, soon get hot enough to leave a negligible amount of wet surface glue. If wet glue is excessive, stacking sticks may be used between panels by the offbearer, but a pinch or two of sawdust has also been found very practical.

Shielding

The Federal Communications Commission has established regulations which limit the permissible radiation (i.e. broadcasting) from any industrial RF equipment to protect against interference with radio communications such as aircraft, police, fire, industrial, broadcasting, etc., and has set a time within which all present installations must comply.

Proper shielding of a new installation is not difficult, nor expensive, and is quite practical for edge- and end-gluing. We work with the press manufacturer on shielding as well as general design and coordination with the RF generator. The complete equipment is then "type-tested" to make sure radiation complies with FCC regulations, and each subsequent user of that design is given a certificate stating that it complies with the FCC regulations.

Fig. 7 shows two views of a typical well-shielded and certified installation, that of an Earle Hart press at Caswell–Runyon in Goshen, Indiana.

Adequate shielding is not merely a matter of metallic enclosure of the press, but requires a special technique acquired solely by experience. Uncertified installations should be inspected by a competent electronics engineer, to determine whether they may be patched up to meet FCC regulations without excessive expense. Engineering assistance is available for this purpose.

Electrode Design

Electrode design depends upon application. Virtually all electrodes for edge-gluing are either staggered or solid, as shown in Fig. 8, and both have their advantages and disadvantages.

Staggered electrodes deliberately set up less than the full glue-line area, because of the criss-cross heating pattern, the remainder setting up within minutes or a few hours after removal from the press. When less than the full area provides adequate strength to hold the boards together, the job is thus often accomplished with somewhat less power for the same time, or in less time with the same power, compared to solid electrodes.

Solid electrodes, of course, set all of the glue-line area, leaving none to be set up after removal from the press. If for any reason it is considered that maximum strength is needed prior to release of pressure, then solid electrodes are desirable and corresponding power and time are required to do the job. Both stag-

gered and solid electrode presses are in wide use for edge-gluing.

The series air gaps shown in Fig. 8 should be avoided whenever possible. Small air gaps encourage arcs if the system is operating near maximum safe voltage, and larger air gaps usually lead to critical tuning and generator instability. The result of an air gap, in any case, is to increase the necessary heating time.

It is now well-recognized that sharp electrode corners must be avoided. Fig. 8 shows the excessive crowding of flux lines at sharp corners, with corresponding high voltage gradients and tendency to arc.

The great majority of edge-gluing installations operate with one electrode grounded and the other "hot" (RF voltage to ground, not temperature) because it usually simplifies the

Fig. 7.—A typical well-shielded and certified RF installation.

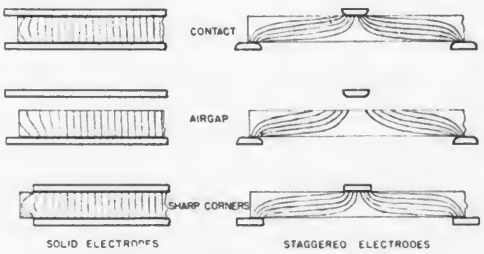

Fig. 8.—Electrode design.

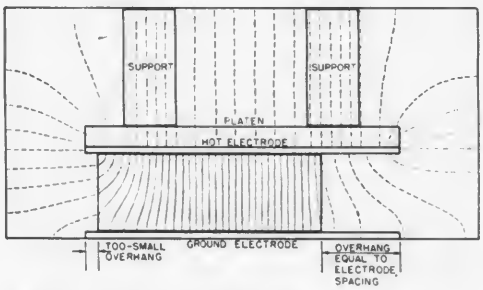

Fig. 9.—How electrode overhang affects uniformity of heating.

generator, coupling and adjustments. The RF current flows not only from the hot to ground electrodes through glue-line and wood, but also, as shown in Fig. 9, through space to the surrounding grounded components of the press. The resulting field is distorted at the electrode edges as shown by the very approximate field flux lines drawn in. These lines also represent current flow; the closer together they are, the more current there is, and therefore the greater the temperature rise.

It is at once apparent that (a) there is uniform current and therefore uniform temperature rise at the center area, (b) less temperature rise at the edges than at the center, (c) less temperature rise near the ends of the grounded electrode than the hot one, and that (d) the greater the electrode overhang, the better the temperature uniformity.

As a working rule, therefore, the electrodes should be arranged so that they always overhang the load by at least its thickness, and preferably twice that. This is a very simple matter for conventional edge-gluing, and results in excellent uniformity whether the system is fed push-pull or grounded.

For very wide glue lines, such as encountered in the lamination of arches and trusses, this effect must be carefully taken into account. For example, if the electrode spacing is 6 inches and the electrodes are only 12 inches by 12 inches in area, there will be such serious field distortion that much more heat will be developed near the hot electrode than near the ground electrode.

A partial improvement for very wide glue-lines is to use push-pull electrodes (both hot, 180° out of phase) with the result indicated in Fig. 10. It is as if a phantom ground electrode had been inserted at the dotted line, with the result that the distortion exends only half as far back beween the electrodes as it did with one grounded. Push-pull electrodes may be fed either from a push-pull generator (called "double ended" by its manufacturer) or by a coupling circuit from a standard grounded-output generator.

The use of push-pull electrodes for wide glue-lines is *not necessary,* however, if the electrodes are made to overhang the load properly; with adequate overhang the heating will be same near either electrode.

It might be mentioned as matter of interest that by judicious adjustment of one or more of the factors (a) electrode size (deficient overhang) (b) electrode shape, (c) subnormal generator power (see below) and (d) above-normal generator frequency (see below) it is possible to spot a point or plane of maximum heat at virtually any desired location between the electrodes.

Electrode Material

Electrically almost any non-magnetic metal is suitable for electrodes. Copper has the desirable high conductivity, but stainless steel is

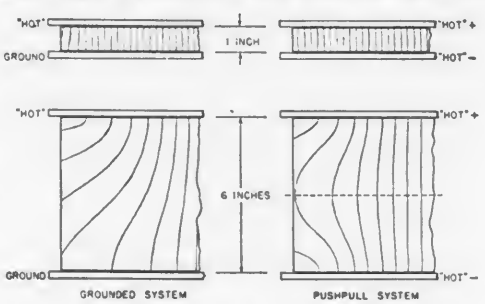

Fig. 10.—Push-pull vs. grounded electrodes.

quite adequate for the purpose, and is perhaps most often used because glue does not tend to stick to it, and occasional arcs do not melt it too easily. Brass is often used. Aluminum is excellent electrically, but arcs eat through it very quickly.

Insulation for the support of electrodes must be chosen and designed carefully, keeping in mind that if RF heats it at all, successive press cycles will keep adding Btu's until it may get too hot and char or blister, causing an arc through it and consequent failure. At the frequencies used for edge gluing, ceramics and glass-bonded mica (Mycalex, Mykroy, etc.) are almost perfect insulators, but expensive and not generally necessary. The phenolics (Micarta, Bakelite, etc.) are not as good insulators, but usually quite adequate if voltage gradients in them are kept low and across the laminations, and adjacent sharp metal corners (including bolt ends) are avoided. Hardboard may be used for thin panel applications. Well-dried and sealed wood is almost as good, and sometimes better than phenolics and is easier to work, but the same voltage gradient precautions are necessary. We recommend maple dried to one percent moisture content, sealed with a low-loss transformer insulating varnish.

Whenever practicable, it is helpful to introduce rubber or any other effective resiliency behind one side of the electrodes, so that the tiny air gaps formed by minor wood thickness tolerances will be minimized. This may permit an increase in voltage without arcs, and, therefore, a reduction of heating time.

End-gluing electrode design requires special consideration which is about the same for batch and continuous presses. Each of the three suggested types of electrode shown at the right in Fig. 5 may be used with any one of the three types of joint shown at the left, with varying efficiencies and results. The solid electrodes heat all of the wood and all of the glue, but the glue is electrically more in series with the wood than it is in parallel with it. The glue-line is so long (high resistance) that relatively less current flows through it from one end to the other. Consequently it is necessary for the RF to heat the wood much of the way up to setting temperature, the wood, *in turn,* heating the glue, the remainder being taken care of by the glue-line current. The result is a relatively poor efficiency, because so much power had to go into wood, requiring more power and/or more heating time. The joint, however, will be completely set up.

Feather edges, unfortunately, will not be set up with any electrode arrangement because of heat loss to cooler electrodes, unless they are maintained at an elevated temperature.

Strip electrodes for end-gluing will perform identically to solid electrodes, except that there will be unbonded areas between electrodes (later set up at room temperature), and there will be a generally better bond around the "hot" electrodes than the cold, due to field distortion if the strip width is comparable to stock thickness. Wider strip widths reduce the latter effect. This arrangement is useful to reduce the power requirements and/or heating time, if the reduced joint strength is acceptable.

If glue on the electrodes is a problem, an air gap may be used with either solid or strip electrodes, but there may then be a moderate increase of heating time to avoid arcs or to maintain generator stability.

Double-grid electrodes may provide better efficiency than solid or strip, because the glue-line path between electrodes is about the same length as the wood path. Most of the power at the joint accordingly goes into the glue line rather than into wood, the ratio of glue to wood per unit volume being much higher than for edge-gluing. In order for the current to flow through the glue lines, it must also flow through some series wood under each electrode, so that the amount of heat in the glue decreases with increasing distance from the nearest surface. When glue near the surface sets, however, its conductivity drops, allowing more power to go into deeper glue.

Air gaps cannot be used with double grid electrodes without (a) an efficiency reduction with most generators, and (b) a substantial increase in size of the unbonded (temporarily) area between opposed electrodes. For some situations these disadvantages may be offset by the mechanical advantages.

Other Facilities

Associated Facilities May Increase Production. The production rate obtained from an electronic press, per day or per man, is greatly

affected by associated equipment. One item already covered in detail is the jointer or ripsaw performance requirements.

Most batch presses require matching of the stock before glue-spread, to obtain approximately the correct layup width for the press and finished panel. At least one plant situation is such, however, that no pre-spread matching is done at all. The layup men match as they lay up, not for final panel width, but only sufficiently to obtain pressure from the 4-inch stroke of the edge pressure feet in the press; this requires negligible time on their part. The offbearer then feeds the glued panels of variable width (within 2 inches to 3 inches) through a high-speed ripsaw equipped with a fence for proper panel size. Out of this offbearing rip come exactly sized complete panels, the excess being fed back to the original jointer to go onto another panel.

The principle of offbearing rip has, of course, long been applied to continuous presses. The incorporation of an automatic cutoff saw might be considered the primary feature of continuous presses.

The RF Generator

The RF generator is nothing more than a frequency changer which converts ordinary 60-cycle power to say 5,000,000- or 10,000,000-cycle power. Being about 50 percent efficient, only half the input power comes out as high frequency, the remainder coming out the cooling system as heat. As a matter of convenience, input voltages are 220 or 440, three-phase, and output voltages (for wood gluing) are adjustable in the neighborhood of 1,000 volts, single-phase. The output is still simple alternating current, identical with the input, except that it alernates so many more times per second.

It is not generally realized that *some* glue-line heat, through infinitesmal, is obtained by putting ordinary 60 cycles, 440 volts, across the electrodes. By using ordinary transformers we can raise the 60-cycle voltage across the glue line until at several thousand volts it will arc through. Even just before such an arc occurs, however, negligible heat is developed in the glue line because the wood is such a poor conductor of 60 cycles, and the glue line makes such poor contact with the electrodes, allowing negligible current to flow through the glue line, therefore developing negligible heat.

Now virtually all materials absorb more power (for the same voltage) as frequency is raised. Thus if we had means to keep say 1,000 volts across the electrodes while steadily raising frequency, we would find that the glue line and wood would absorb energy faster, in turn, causing their temperature to rise at faster rates. Hence, we use high frequency as a means of getting the glue and wood to absorb energy, without increasing the voltage.

The purpose of an RF generator, then, is to supply sufficient power at the right frequency and voltage, and nothing more. If it supplies the correct frequency and voltage across the loaded electrodes, but the bond is imperfect, the difficulty cannot be in the generator, coupling, or tuning circuits; they are doing their job. But let us review the desirable characteristics of a generator:

Power Output

Power output is determined by the pressload. Since a few generators are rated on power input, or Btu. output, instead of National Electrical Manufacturers' Association standard power output, one must always be careful to ascertain the power *output* rating of a generator, and to use that alone in calculations. Moreover a few generators are rated for intermittent duty, giving them an apparently higher power output. While most generators are indeed used on intermittent duty, there are times when virtually all of them are used for long continuous periods, so it is much safer to use *continuous* duty power *output* ratings in calculations.

Table 3 shows a very convenient formula for calculating edge-gluing time or power requirements. It is universally applicable to conventional edge-gluing situations and appears to hold quite well for most special applications such as the lamination of trusses and arches, having been derived from production results on

TABLE 3.—HEATING TIME CALCULATION

$$PTA = 18G + MW$$

P = Power, generator output, kilowatts
T = Time, heating, seconds (15 to 20 minimum)
G = Glue-line area, square inches
M = Moisture content of wood, percent (4 min.)
W = Wood volume, cubic inches

Press:		Batch		Continuous	
Electrodes:		Staggered	Solid	Staggered	Solid
A =	Softwoods:	100	80	94–118	94
	Hardwoods:	56	44	52– 65	52

many installations of a number of makes and types. Because it lumps together a number of secondary effects such as those due to glue formulation, frequency, species, stock temperature, etc., it can only be approximate, perhaps within 20 percent. An example of the calculation is given in Table 4.

TABLE 4.—TIME CALCULATION EXAMPLE

Pressload = 1 inch by 40 inches by 80 inches,
Stock = 1 inch by 2 inches
Glue-line Area $G = 19 \times 1 \times 80 = 1520$ square inches
Wood Volume $W = 40 \times 1 \times 80 = 3200$ cubic inches
Moisture Content $M = 7$ percent
Power Output $P = 22$ kw.
Batch Press, Staggered, Softwood: $A = 100$

$$T = \frac{18G + MW}{PA} = \frac{18 \times 1520 + 7 \times 3200}{22 \times 100} = 23 \text{ Sec.}$$

It is important to note that 4 percent is the minimum moisure content to enter in the formula, even though the actual moisture content may be lower. This is done because a further drop does not significantly reduce wood energy absorption.

Likewise, if the heating time, using the formula, calculates less than 15 or 20 seconds, a lower power should be used to obtain a longer time. Times below 15 to 20 seconds will nearly always dry the glue, but they do not necessarily give it time to polymerize properly, thus may result in a poor joint. Also times below 15 to 20 seconds often require excessively high voltages and a corresponding danger of arcs.

Time in excess of 60 seconds, for conventional edge-gluing of approximately 4/4 stock, generally do not permit the realization of the main cost savings of RF gluing. If the formula gives a time in excess of 60 seconds, more power should be used to cut down the time.

Heating times greatly in excess of 60 seconds on say 4/4 stock introduce another effect, illustrated in Fig. 11. Suppose the power is so reduced that a bond should be obtained in 4 minutes instead of 20 seconds. In four minutes time there will be considerable (a) loss of heat from the glue line to cooler adjacent wood, thus further increasing the time to (perhaps) 5 minutes for a good bond, and (b) loss of heat from glue line (a good heat conductor) to the cooler electrodes, resulting in less temperature near the surfaces than in the center. Further compensation to get the glue near the surface to bond, without increasing power, might take ten minutes total heating time. In other words, far insufficient power necessitates a more than corresponding increase of heating time.

Experimentally it is possible to use this effect of low power and long times to actually char the center region between electrodes, leaving uncharred regions near and at the surface due to heat losses therefrom. A few investigators have believed this to be due to a "standing wave" between electrodes, but nothing in our experience has indicated other than uniform current and voltage gradient in uniform material placed in a uniform field. The uniform current, flowing from one electrode to the other through uniform material, produces uniform voltage gradient and uniform heat input to the material, but the temperature rise of any portion depends upon how much of that heat is retained and how much is lost to cooler surroundings.

For stock thickness of 3 inches to 6 inches, however, times of 3 to 5 minutes are often quite logical, and can take advantage of the fact that glues set at a lower temperature the longer it takes to reach that temperaure, which effects some power economy.

A corresponding formula for end-gluing has not been devised, but this same formula should at least provide a fair approximation.

In practice one must begin with his anticipated production rate, assume a convenient press size for the shape and size of panels to be made, and then assume a generator *continuous* power output rating to calculate the heating time. If it falls below 15 or above 60 seconds, recalculate using less or more power, respectively. Then (using the example of Table 4)

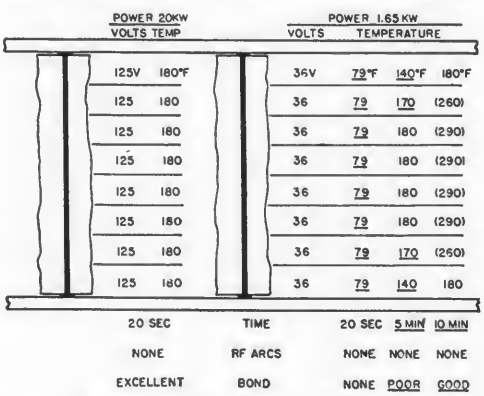

Fig. 11.—Relation of power to time.

if the reload time (see Press Reload Time) is 15 seconds, the total press cycle is 15 plus 23, or 38 seconds, so the number of pressloads for seven hours of actual operation is 3,600 × 7/38 or 662. If the 40-inch by 80-inch layup consists of eight 20-inch by 20-inch panels, this is 8 × 662, or 5,296 panels per shift, or 662 × 3,200/144 or 14,700 board feet per shift, if the fresh stock and layup men keep up with the press.

Assuming an optimum power of 20 kw. has been chosen, and that this power produces exactly the maximum safe electrode voltage to avoid arcs (say 1,000 volts), and that a good bond is obtained in 20 seconds, Table 5 shows the effect of altering this power upward or downward. Halving the power, of course, increases the heating time correspondingly. Doubling the power produces excessive voltage and probably arcs. If the arc does not happen to occur, the bond will be obtained in half the time, but this is hardly a dependable mode of operation.

TABLE 5.—RF POWER AND FREQUENCY

Power	Time		RF			Wood Temp.	Glue Line	
	Seconds	Excess	Power	Volts	Arcs		Temp.	Bond
Halved	40 Sec.	100 percent	10 kw.	707 V	None	80°F	180°F	Excellent
	20	0	10	707	Non	75	125	None
Optimum	20	0	20	1000	None	80	180	Excellent
Doubled	20	0	40	1414	Arc	90	290	Burn
	10	----------	40	1414	Arc	80	180	Excellent
Frequency								
Halved	28 Sec.	40 percent	12 kw.	1000	None	77°F	180°F	Excellent
	20	0	20	1288	Arc	78	199	Excellent
Optimum	20	0	20	1000	None	80	180	Excellent
Doubled	20	0	20	766	None	82	161	Fair
	24	20	20	766	None	84	180	Excellent

Selection of Frequency

Optimum Frequency depends upon the application, and is determined by the generator manufacturer who must weigh a number of factors. High frequency reduces electrode voltage and avoids arcs, while lower frequency decreases the complexity and cost of tuning systems and generally puts a greater proportion of power into glue rather than wood. Five to 6.8 MC is generally used for edge-gluing, but 13.6 MC is desirable in a few specific cases.

Shielding

Generators must be shielded. In order to comply with FCC regulations, all generators *must* be certified that they so comply. Responsible manufacturers recognize this and supply certificates with the generator, in our case actually affixed to the door of the equipment.

Voltage Variation

Line Voltage variations must be tolerated. Most generators can handle plus or minus 5 percent variation without ill effects, but greater variations will shorten tube life. If greater variation is unavoidable, automatic regulating transformers should be used for the generator oscillator-tube filaments. In fact, it is possible to increase tube life with automatic transformers even if the regulation is within 5 percent. There is no need, however, to stabilize the entire input to the generator, as variable plate voltage has no effect on tube life. It does, however, affect power output; a 10 percent line voltage drop causes a 10 percent increase in heating time if the operator maintains constant plate current, or 20 percent if he does not, so wide fluctuations are to be avoided.

Tuning

Tuning must be simple, the arrangements varying with the manufacturer and with the application, their purpose being always to act as a variable-ratio transformer to vary the voltage across the electrodes.

Generators containing a complete "high-loaded Q" tank circuit, as contrasted to those which make the electrodes part of the tank circuit, will permit (a) automatic *raising* of electrode voltage during the heating cycle, thus shortening the heating time, and (b) location of the generator any distance up to 30 or 40 feet from the electrodes if necessary.

Manual or motor-controlled tuning is usually adjusted by the edge-gluing foreman when there is a major change of load thickness, number of glue lines, area, etc., by merely adjusting to a specified value on a panel meter. There is no need for attention between major changes.

Automatic tuning can be used, but it adds complexity and a requirement for increased technical maintenance skill. Our experience with automatic tuning for edge-gluing and other RF heating applications shows that there is usually no real economic advantage in using it, particularly with generator designs which permit inherent raising of electrode voltage during the heating cycle.

Importance of Designer Experience

Good design requires experience. Virtually all generator manufacturers use the oscillator tubes singly or in parallel, with one side of the output grounded. It is generally felt that this simplifies design and adjustment, reduces cost, and facilitates remote generator location if desired. It also permits continued operation at half power in case of failure of an oscillator tube, and requires no balancing controls.

Tube life is primarily a matter of (a) experienced tube design, (b) experienced generator design, (c) good line voltage regulation as discussed above, and (d) use of the equipment within manufacturer's ratings. If these factors are satisfied, an average life of 5,000 hours may be obtained. Occasionally, one will die at 1,000 hours, but many are still in operation at 15,000 hours.

The RF generators used for edge gluing are of standard design, also being used for wood lamination, cabinet assembly, plastic moulding, rubber preheating, curing, and drying, etc.

There is no substitute for experienced generator design and workmanship. Even those generator manufacturers with ten or fifteen years of successful medium- and high-power broadcast transmitter design behind them found serious and unanticipated hurdles when their RF generators got into the field. This sad and costly experience has led to generators, most of which today are very foolproof and dependable, requiring only a reasonable amount of maintenance. Without the benefit of this experience, it is almost a foregone conclusion that any radio "ham" (and I am a ham) attempting to design and build a generator for edge-gluing will wind up spending several times as much time learning how to make it work dependably as he did to design and build it.

The Installation

Adherence to the foregoing suggestions, to the best practicable degree, particularly in regard to stock preparation, will assure higher production rates and much *lower costs* per board foot of panel than otherwise now obtainable. Radio frequency gluing is a very high-speed tool, whose full economic advantage is sometimes not realized without correspondingly improving associated facilities. Glues have progressed very fast, and will continue to do so, to take even further advantage of the RF tool. Stock preparation techniques are improving.

The writer is indebted to Messrs. T. P. Kinn, M. P. Vore, R. E. Kirby and C. P. Bernhardt of the Westinghouse Engineering and Sales Departments for their many contributions contained herein, born of long and sometimes sad experience with many hundreds of RF heating installations.

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APPENDIX

As indicated at the beginning, the estimated values in Figs. 3, 4, 6, 11, and Tables 1, 2 and 5 were calculated on these assumptions:

1. Press size and one-inch thick load such that 20 kw. generator output normally produces 1000 volts across the electrodes, raising the glue line temperature from 70° F. to 180° F. in 20 seconds. Glue assumed to set immediately upon reaching 180° F., regardless of excess time.
2. Maximum safe voltage $V = S^{0.8}$; that is, 1000 V at 1 inch, 330 V at ¼ inch, 189 V at ⅛ inch.
3. Power in normal load divides half to glue lines, half to wood. Glue conductivity effectively twice that of wood.
4. Generator loaded always to 20 kw. (alternatively to 10 kw.), unless detuned back to lower voltage to avoid arcs.
5. Brackets ( ) indicate what result would be without (a) arcs, or (b) loss of moisture.

The pressures indicated in Fig. 2 are not calculated, but estimates based on the geometry. The flux lines in Figs. 5, 8, 9, and 10 are drawn only approximately, without the aid of "curvilinear square" technique.

Discussion

From Floor: Is there a simple way to determine whether an edge has been jointed or ripped properly?

Mr. Winlund: If adjacent edges, prior to glue-spreading, are held together up to the light, it should not be possible to see light through any crack. This rule is especially valid for wide and/or long stock, but some light may be tolerated for relatively narrow stock, because the latter will bend more under edge-pressure.

This test only indicates relative straightness and flatness, however. Off-square edges are usually detected by a one-sided bond after the RF cycle, after making sure the glue-spread is uniform at the time of lay-up.

Mr. Merrill Stover (The Borden Company): Mr. Winlund, you mentioned that the Federal Communications Commission has set a time by which all RF gluing installations must conform to the rules. When is it, and what is involved to shield present equipment to conform?

Mr. Winlund: The time is June, 1952. It was established in 1947, giving everyone five years to comply.

Accordingly, we redesigned our equipment and for the past few years have furnished only generators certified to meet FCC rules. We have also assisted certain press manufacturers with proper shielding, with the result that the entire installation can be automatically certified upon installation.

The problem of existing uncertified installations is quite complex. Many are quite obviously unshielded and may have to be completely replaced. Many may appear to the layman to be shielded, yet may radiate very excessively. It should in some cases be possible to patch up the leaks, run a survey, and certify the installation. It is necessary for a competent engineer to see and study the installation to determine whether it can be sufficiently well-shielded with reasonable expense.

From Floor: I understand shielding is not necessary if the frequency is kept within the FCC assigned bands. If the generator has an indicator lamp on the panel, showing when frequency is in the band, cannot shielding be ignored?

Mr. Winlund: If the indicator shows when frequency is *about* to move out of the band, and if the operator *continuously* watches it and retunes so it *never* goes out, then yes, shielding is not required by law.

However, we are not aware of any generator on the market having such a precise indicator. An indicator lamp connected to a wave-meter behind the panel is far too broad. Furthermore, the cost of an operator to watch the lamp and continuously retune, even if it did indicate reliably, would very quickly pay for the cost of initial equipment shielding.

Mr. M. E. Dunlap (Forest Products Laboratory): In work at the Forest Products Laboratory and in contacts with the industry accuracy in the machining of material for edge gluing has been found most important. It is just as necessary for accurate work where high-frequency dielectric heating is used as for any other type of gluing operation. The control of moisture content, particularly the uniformity of distribution is likewise important.

Edge temperatures may be maintained or controlled by the use of low density fiber board edgings or by the use of a wet film of paper placed between the fiber board and work. The latter is placed perpendicular to the electrodes. Heat is generated first along the sides of the work and is applicable to technical gluing rather than routine gluing operations.

The suggestion of gluing pressures involving the crushing of wood are probably somewhat dangerous because of weakening the wood.

Mr. Winlund: Perhaps we should not have referred to pressures "capable of crushing wood" because the actual use of such pressures, of course, does weaken the wood. Our main point is that husky presses are needed, and sometimes pressures close to crushing are needed to get a real bond. If the pressure feet are thinner than the stock, as they usually are, wood may be indented along the pressure-application edge without getting too close to crushing at the gluelines.

Mr. Dunlap: What surface pressure is required to keep the boards flat in an edge gluing operation and still not prevent loss of edge-pressure due to platen friction?

Mr. Winlund: Pressures up to about 10 psi. are used on most batch presses. Regarding

platen friction, it is very desirable to provide a "breathing" cycle such that immediately after edge-pressure is applied, surface pressure is momentarily removed and reapplied, permitting equalization of edge-pressure throughout the panel. Without breathing, it is not uncommon for the edges to never quite meet on the side away from edge-pressure application. Breathing completely removes this possibility.

From Floor: All generators seem to indicate a drop in current as the glue dries out in an edge-gluing load. Does this mean full power is obtained only at the beginning of the cycle, and if so, wouldn't automatic tuning help to reduce the time?

Mr. Winlund: You are correct that plate current, and therefore power output, is always highest at the beginning of the cycle. Also the power output could be kept constant with suitable automatic tuning devices if there were sufficient justification.

Generators designed to make the load part of their tank circuits, which are those requiring location very close to the press, maintain rather *constant voltage* across the electrodes. As the glue dries out, current drops; and, therefore, power drops proportionately.

Generators designed complete with an internal tank circuit, which are those that may be operated either close by or up to 30 or 40 feet from the press, may be so electrically coupled to the load that electrode *voltage rises* considerably during the heating cycle. Thus, as the glue dries out, RF current drops, but *not* as much as with constant voltage, so the power (proportional to both current and voltage) does not drop nearly so much. It is analogous to over-compounding a generator. The result is a higher average power, and a shorter heating cycle.

Mr. E. D. Marshall (Texas Forest Service): Is it best to apply pressure before turning on the RF?

Mr. Winlund: Nearly all presses apply full pressure before turning on the RF. If for various reasons the pressure must be so high as to squeeze out excessive glue, this problem is met by alteration of the glue so that it will not flow out so easily.

However, there are a number of presses which automatically apply RF before edge-pressure reaches its maximum, partially drying it to prevent excessive flow out of the joint.

Mr. Everett L. Ellis (University of Idaho): Reference in title is made to end-gluing. By this do you mean scarfing; and, if so, what differences are apparent as contrasted with edge-gluing?

Mr. Winlund: End-gluing refers to scarfing, finger joint, or zee joints. The differences in contrast with edge-gluing are given in the published report.

Mr. Philip Reinmuth (Potlach Forests, Inc.): Are there any continuous process RF gluing machines available for the gluing of veneers; if so, with what success in using both thin and thick veneers?

Mr. Winlund: There are several continuous veneer RF edge-gluing machines on the market. The Kiehl veneer splicer is quite successful, especially with veneers up to $\frac{3}{16}$" thick. Much work is also being done on RF plywood veneer splicers, with promising, though somewhat experimental, results.

Mr. R. G. DeMoisy (Institute of Forest Products, University of Washington): Dr. Hall gave me two minutes to tell this group about one of the projects of the Washington Institute of Forest Products. We are currently engaged in an inventory of unused wood resources of the entire State of Washington. Purpose: to interest and aid investors in locating new industries and greater payrolls within the State by pointing out sources and volumes of available unused raw material.

The first report of four northwestern counties indicates 1,627 cu. ft. per acre left over from logging and a total of 35 million cu. ft. of available material from logging, milling and intermediate cutting. Present indications are that more than 200 million cu. ft. of raw material will be revealed, or $50,000,000. in payroll terms. I would appreciate interested parties giving me their names and addresses which I will add to our mailing list.

Wood Waste in the Douglas Fir Region*

F. W. Guernsey

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The need for increasing the utilization of all forest products is apparent when the per capita consumption of wood and pulp products is examined. To implement the aim of the Food and Agriculture Organization of the United Nations to raise the standard of living throughout the less developed nations, more of the products of the forest must be consumed.

In the Douglas fir region of Oregon, Washington, and British Columbia, it is estimated that the forest yield would be increased 20 to 25 percent if the residue now being left in the woods could be utilized.

In the sawmills of the region utilization of the waste is fairly complete, but at present this material is diverted to relatively low value uses. Revenue to the mills in one area, at least, amounts to only 2.3 percent of the value of the lumber produced, indicating considerable room for improvement in economic utilization.

Introduction

INCREASING demands for all types of forest products, together with decreasing supplies of accessible virgin timber, have resulted in a broad program for the maintenance of forest land at full productive capacity and for its protection from fire, disease and insects. Closely associated with these problems is that of utilizing to the best possible advantage the material harvested from the forest. This involves a reduction in the large volume of so-called waste resulting from conversion of the standing tree to its final use.

The Third World Forestry Congress, held at Helsinki, Finland, in July, 1949, recognized this when it recommended:

"The encouragement of integration of the various wood-using industries . . .

. . . that efforts should be made not only to expand outlets for wood waste but also to create new ones in conformity with technical and industrial progress . . .

. . . that special attention should be given to the grading of timber in order to ensure to each product its appropriate use . . .

. . . that scientific research aiming at the utilization of wood waste should be continued and increased from the physical, chemical, mechanical and biological point of view . . .

. . . that in order to attain these aims, the laboratories concerned are invited to co-ordinate scientific and technical research and F. A. O. should collect and disseminate information on the result achieved in various countries." (*1*) .

In order that the need for utilizing all available wood supplies may be appreciated, a short review of the world situation as reported in various publications of F. A. O. is presented.

Europe and North America together produce about 45 percent of the world's output, although they possess only 29 percent of the world's accessible productive forest. Latin America and Africa, with 34 percent of the world's forests, produce about 15 percent of the output. South and East Asia and the U. S. S. R. together produce about 38 percent.

The annual consumption of wood per capita varies tremendously and is shown as follows:

North America (excluding Mexico)	78	cu. ft.
Oceania	74	"
Latin America	46	"
Europe	28	"
Africa	10.5	"
Asia	3.5	" (2)

Accepting these figures as the present range of consumption there is obviously a need in many countries and continents for a substantial rise in the consumption of wood in all its forms. This need is greatest in the Far East and Near East but it exists also in heavily forested regions such as Latin America and Eastern Europe where low incomes keep wood consumption down. The current volume of wood output cannot meet present needs, and unless production is substantially increased, will not meet future needs, since the world's population is increasing at the rate of one percent yearly. The forest output must therefore be expanded.

* Published with the permission of the Director of Forestry, Dept. of Resources and Development, Ottawa.

One of the yardsticks of the standards of living of a nation is the quantity of pulp and paper products consumed by its people. The F. A. O. Year Book Forest Products Statistics, 1948, gives some idea of the annual quantities of pulp used per capita in the following zones:

North America (excluding Mexico)	244 lbs.
Australia and New Zealand	103 "
Europe	46½ "
Latin America	33 "
Near East and North Africa	4½ "
South and East Asia	0.9 " (2)

Here again it would appear that pulp production must be increased if per capita consumption is even to be maintained.

The United States and Canada produce 67 percent, and Europe 26 percent of the world's pulp products. According to a Report on World Pulp Problems by F. A. O. an appraisal of the forest situation in the United States, published in 1948, indicates that total growth and total drain are more or less in balance. There is, however, an indicated overcut of 23 percent in the coniferous forests which provide 85 percent of all the pulpwood cut. It is estimated that the larger sizes of trees which currently make up a major part of the pulpwood supply are being overcut at the rate of 50 percent. Despite this condition, the annual production of pulpwood in the United States is expected to increase 180 percent in the next 50 years, lumber and sawn products to remain more or less stable and fuel-wood to decrease.

One of the methods by which this increased production is to be accomplished is by the closer utilization of residue now being left in the woods after logging or destroyed in refuse burners during the manufacture of lumber.

This article deals with the utilization of so-called waste in the Douglas fir regions of Oregon, Washington and British Columbia.

Logging Waste

Logging in these regions is by high lead or modifications of the high lead system with heavy Diesel or steam equipment. Transportation from the woods to the log dump is by railroad or truck—the latter system gradually replacing the former in the more recent operations. The system is designed for high speed production, but it is probably the most wasteful in the world since it causes considerable breakage and the size and weight of the equipment make it unprofitable to harvest much of the sound wood in the form of small logs and broken chunks. The debris is heavy, and although frequently it is not considered merchantable, it contains much wood material which should have some useful purpose. Both sawmills and pulp-mills have been designed to handle large logs, and with a plentiful supply of high grade material there has been little inducement to harvest small wood. During and since the war more and more interest has been shown in the recovery of small wood left as residue and many studies have been conducted in Oregon, Washington and British Columbia on the quantity, quality, and value of this material.

Table 1 shows the results of several of these studies over a period of years and indicates the uniformity of the percentage of waste throughout the whole area.

There are three general methods of removing small material:

(a) Pre-logging.
(b) Clean logging.
(c) Re-logging.

Pre-logging is the process of felling and yarding small trees before the main operation.

TABLE 1.—PERCENTAGE OF RECOVERABLE WASTE FROM LOGGING OPERATIONS

Reported by[1]	Area	Sound material per acre		Percent of original volume
		Ft.b.m.	Cords	
A. H. Hodgson 1930 (3)	Washington and Oregon	21, 400[a]	42	19.7
J. H. Jenkins & F. W. Guernsey 1931 (4)	British Columbia	16, 500[a]	27	19.5
Oregon Forest Products Laboratory 1944 (5)	Oregon	26, 408[b]	51	21.0
Comox Logging Co. & B. C. Forest Service 1944 (6)	British Columbia	7, 440[b]	15	19.0
U. S. Forest Service & Dwyer Lumber Co. 1948 (7)	Oregon	12, 000[c]	24	---
Forest Products Laboratory, Vancouver 1948	British Columbia	19, 950[a][d]	40	25.0

(1) For authorities reporting literature cited at end of paper.
(a) Estimate only of recoverable waste (probably too high).
(b) Actual volume removed in experimental logging.
(c) Based on estimate of residue.
(d) Sixty per cent of the volume of this material was 8 inches and over in diameter and 10 feet and over in length.

Clean logging is felling and yarding all material, both large and small during one operation.

Re-logging is the removal of the small material and residue after the main operations.

The three methods are being practised in the region and the method selected depends on many factors. Pre-logging and re-logging operations generally use special light mobile equipment for yarding and loading the small material.

The utilization of logging waste is mainly for pulpwood. In 1948, in Washington 7.73 percent of the total volume of wood used for pulp manufacture was derived from logging salvage. (*8*) This is probably much greater than in either Oregon or British Columbia. The hydraulic barker and whole log chipper have simplified, to some extent, the handling at the pulp-mill. The processing of salvage wood from the Comox Logging Company study (*6*) indicated that the strength of groundwood from the salvaged hemlock was slightly below that of average hemlock logs, and that the strength of groundwood from Douglas fir was less than that of poor hemlock. This condition may have been due to the long periods during which the material lay in the woods. The wood also had about three times the dirt-making properties of normal pulp logs, but this could possibly be greatly reduced by the elimination of very knotty logs. Pulp yield of both hemlock and Douglas fir was higher than that of normal hemlock pulp logs.

Logging waste also has a value when converted to lumber. Table 2 shows the results of two studies on the grade recovery of salvaged logs. Study No. 1 (*5*) was conducted by the Oregon Forest Products Laboratory in co-operation with a portable sawmill, and Study No. 2 (*7*) was conducted by the Pacific Northwest Forest and Range Experiment Station, the U. S. Forest Service, and the Dwyer Lumber Company, using a Swedish type gang mill.

TABLE 2

Grade	Study No. 1 Percent recovery	Study No. 2 Percent recovery
C Clear and Better	3.4	1.3
Select Structural	2.1	3.2
Select Merchantable	6.1	0.7
Posts and Timbers	6.5	----
No. 1 Common	6.3	34.1
No. 2 Common	42.4	42.2
No. 3 Common	25.5	11.7
No. 4 Common	7.7	6.8
Total	100.0	100.0

There are many factors affecting the recovery of logging waste, the main factor being economic. Costs are higher even when light mobile equipment is used and often a slight downward trend in the price of sawlogs will affect the utilization of waste material. Pulp mills are reluctant to take too great a volume since they are still geared to handle the larger logs and salvage wood creates more dirt than normal logs. The effect of decay on the residue also has an important bearing on its utilization. Studies are being conducted by the Forest Products Laboratory, Vancouver, on the effect of deterioration in quality of logging residue and on its utilization for pulpwood in the coastal region of British Columbia. The study has not progressed to a point where definite conclusions can be stated but indications are that deterioration of hemlock and balsam (true fir) becomes apparent within one year of the original logging. Several new fruiting bodies of fungi were noted on one-year-old residue, pockets of incipient decay in the sapwood of two-year-old, and pockets of advanced decay in three-year-old material. The wood-destroying fungi noted were mainly those which attack cellulose, producing brown rot.

Sawmill Waste

The utilization of sawmill waste does not present the same problems as logging waste. Most mills are in, or close to, centers of population where transportation facilities are available and the material is more readily disposed of in some form or another. Consequently the utilization of sawmill waste in such areas is fairly good, although many of the small and medium-sized mills in outlying districts still destroy most of their residue.

The waste is of a diversified character and consequently does not lend itself for use in any one product. It may be classified as follows:

Solid waste (slabs, edgings and trim).
Sawdust.
Shavings.

Solid waste can be utilized in many forms, a few of which are:

Lath.
Broom handles.

Shingle bands.
Pulpwood and chips (pulp and board).
Fuel.
Hogged fuel.

Sawdust at the present time is used mainly for fuel, either by the mill for the generation of power or by domestic and other consumers. Shavings at the present time are used almost exclusively for fuel by the mill, or compressed into fuel briquettes.

TABLE 3.—PERCENT OF CUBIC VOLUME CONVERTED TO SAWMILL WASTE IN THE DOUGLAS FIR REGION

	Oregon(9)	Oregon and[1] Washington	British[2] Columbia	Average
Solid waste	19.1	19.3	14.5	17.6
Sawdust	14.5	14.1	17.8	15.5
Total	33.6	33.4	32.3	33.1
Total rough green lumber	66.4	66.6	67.7	66.9

[1]See Literature Citation (10).
[2]See Literature Citation (11).

The production of shavings, which does not decrease the board footage and actually increases the value of the lumber amounts to 8.9 percent of the total volume of waste in Oregon and 9.0 percent in British Columbia.

Assuming that 1000 ft.b.m. of logs contain 162 cubic feet of wood and that one cord of solid waste contains 65 cubic feet of wood (exclusive of bark) every 1000 ft.b.m. of logs cut will produce 28.5 cubic feet or .44 cords of solid residue. Also assuming that one unit of sawdust contains 80 cubic feet of solid wood, every 1000 ft.b.m. of logs cut will also produce 25 cubic feet or .31 units of sawdust.

Most of this waste material is used for fuel, either by the mills for developing their own power or sold as domestic or industrial fuel. In 1944 approximately (*8*) 71 percent of the residue was used for fuel in Western Oregon, 86.3 percent in Western Washington (*10*), and 71 percent in the coast region of British Columbia (*11*).

The percentage of residue sold for pulpwood and chips was 5.1 in Western Washington, negligible in Oregon (*10*) and about 4 percent in British Columbia.

Less than one percent of the waste is converted to lath, broom handle squares, or other products in Washington and Oregon and about 1.5 percent in British Columbia.

Approximately 28.7 percent of the waste is not marketed in Western Oregon, 8.1 percent in Western Washington and about 8 to 12 percent in British Columbia.

The value of the various products is not known in Oregon or Washington but their value has been computed for British Columbia, based on values obtained from the Dominion Bureau of Statistics for 1947.

They are as follows:

	Value per Cubic Foot
Broom handle squares	$0.62
Lath	0.58
Shingle bands	0.41
Pulpwood and chips	0.11
Solid fuel	0.04
Sawdust	0.03
Hogged fuel	0.02

While the above values refer only to British Columbia, the relative values in Oregon and Washington are probably of the same order. In the coast region of British Columbia in 1947 the total value recovered from sawmill waste products amounted to only 2.3 percent of the value of the lumber produced. This indicates that there is room for improvement in the economic utilization of the various products.

Many factors affect the utilization of sawmill waste. Much of the material now being destroyed is unsuitable for anything except fuel, and even much of this must be processed in some way to make it desirable for domestic use. On the other hand, much of the material now being sold as fuel would benefit the sawmill in increased revenue by its conversion to pulp chips or other more valuable products. Since fuel is a necessity in our economy it is likely that sawmill waste will continue to be used for this purpose in some form or another.

One of the most pressing problems, however, in British Columbia at least, is the utilization of hemlock sawdust, and solid waste too small for pulp chips. It is not a popular fuel since its moisture content, green, is too high and its calorific value is lower than that of Douglas fir. Any processing into fuel briquettes will require the evaporation of water at least equal to the weight of wood material. Even when this material is converted to hog fuel for industrial use, it must be mixed with shavings or oil to insure satisfactory burning.

Cedar waste, both from sawmills and shingle mills, presents a similar difficulty.

As a step toward solving these problems, the Forest Products Laboratory in Ottawa is studying the board-making qualities of cedar wood and cedar bark. The Laboratory in Vancouver is studying the extraction of tannin from the bark of salt water floated hemlock logs. One of the potential uses for this tannin is in oil drilling mud where salt content apparently is not a deterring factor. Laboratory tests by one oil company indicate that it may have possibilities.

Conclusion

The problem of the utilization of waste is a complex one. Large organizations can afford the capital outlay necessary to develop pulpmills, board plants and so forth to utilize to best advantage the product of the forest. There is, however, the problem of small and medium-sized operations where means are limited and where location may preclude them from selling to converting plants. It would appear that for them, at the present time at least, minimum returns from their waste products must be expected.

In the meantime, research organizations and industry will continue to work on the problem, gradually developing new uses and products, thereby increasing the utilization and value of the present residue. Coupled with this development should come new methods and machines to utilize the smaller logs that will be available from the vast areas of second-growth soon coming into production.

World shortages of wood and pulp products, and overcutting of our virgin forests, make it imperative that proper utilization of all forest products be practised. If and when the economic unbalance of the world is overcome, wood products of all kinds will play their part in raising the standard of living of the less developed countries. Logging and sawmill waste will then become too valuable to leave on the ground or to destroy in a mill burner.

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Discussion

Mr. Rollo F. England (State of Washington Institute of Forest Products, University of Washington): What can small and medium-sized sawmills do, especially those some distance from converting plants, to utilize their waste?

Col. W. B. Greeley (West Coast Lumbermen's Association): A promising development to assist small sawmills in utilizing waste is the installation of simple mechanical loading devices by pulp mills interested in building up a new source of raw material. These pallets or chain slab loaders are installed by the pulp mill as sawmills release quantities of material and transportation facilities justify them.

Mr. T. E. Kelley (Washington State College): There is a necessity for a market survey of intensive nature that be made available to small operators. Reducing slabs to uniform size aids in waste treatment.

Mr. Guernsey: Some form of co-operative effort between the sawmills and users of waste products will be necessary to assist the saw mills.

Mr. E. J. Reichman (Simpson Logging Co.): Are values for waste products net figures, that is, are capital investment costs taken into account?

Mr. Guernsey: No, they are merely returns.

Mr. E. D. Marshall (Texas Forest Service, A & M College): Your paper indicates that broom handle squares give the greatest return per cubic foot of product. What was the percentage residue after manufacture of broom handles as compared to manufacture of pulp?

Mr. Guernsey: Our studies show that about 56 percent of the volume of waste is of suitable size for manufacture into handle squares. It is also estimated that about 400 to 500 squares are produced from one cord of wood waste. A rough estimate shows that one cord of mill waste will produce one unit of chips.

WOOD AWARD THESIS

The Effect of Fundamental Glue-Line Properties on the Strength of Thin Veneer Laminates

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Introduction

WOOD fulfills an important need for an engineering material to be used where high strength requirements are combined with rigid weight limitations. Lamination of veneer is a method by which wood may be modified to minimize the influence of characteristics that may tend to reduce its superiority over other materials. Significant advantages of glued veneer construction are the elimination or controlled location of material of unreliable strength properties and the possibility of attaining efficiently whatever degree of strength may be desired in the laminated product. During the war, both plywood and laminated wood proved indispensable in aircraft and boat construction where exacting weight and strength requirements must be fulfilled. The full potentiality of wood laminates can only be realized, however, when a complete knowledge of their strength and physical properties is gained.

In current design practices, only the inherent strength of the wood constituting a glued assembly is considered *(2 4 5 6)*. The effect of the adhesive is neglected regardless of its percentage in the composite structure. While an increase in strength properties resulting from lamination has been recognized by at least one American investigator *(11)* and is considered in plywood strength computations by German technologists *(7)*, dependable information necessary to its application is largely lacking. This investigation is part of a more exhaustive study undertaken to contribute to the knowledge of the strength and physical properties of veneer construction in both laminate and plywood forms and thereby to enhance the precision of design techniques.

Scope and Purpose

Although the synthetic resin adhesives manufactured in the United States may be segregated into major types depending upon their principal constituents, significant chemical and physical variations may exist within a general type. In addition, it is recognized that many species of wood have different bending properties. It is therefore probable that different wood-resin combinations will exhibit properties which depart in varying degrees from those of the wood involved. This discussion is limited to one species of wood laminated with one adhesive. Although the information gained does not lend itself to direct application to other combinations, it does indicate an important influence of fundamental glue line properties on a veneer laminate.

The specific objective of this study is to determine to what extent yellow-poplar (*Liriodendron tulipifera* L.) veneer laminates, bonded with a phenol-resorcinol-formaldehyde adhesive, differ from solid wood in tensile and flexural strength and elastic properties. Fulfillment of this objective required an investigation of the effect of horizontal shear on the deformation of laminated beams, which involves (1) an indirect method of determining modulus of rigidity, (2) a method of correcting Young's modulus for the influence of horizontal shear, and (3) a simple direct method of determining pure Young's modulus in bending.

Procedure

Design of Experiment

Any effect of an adhesive on the bending and tensile strength properties of laminated material should become increasingly more pro-

nounced if, in successive panels, the veneer thickness is decreased and the adhesive spread is held constant. If a sufficient range of thicknesses is used, the limits of influence should be clearly reflected. Therefore, assemblies of 1/10-, 1/20-, 1/40-, and 1/60-in. veneers were used in the fabrication of panels for mechanical testing.

Three panels of each of the four veneer thicknesses were prepared, using sufficient sheets of veneer to give a laminate thickness of approximately 0.3 in. Two tension and two bending specimens were taken from each panel. In all, six beams and six tension specimens of each veneer thickness, representing three complete replications, were fabricated for testing.

Fabrication of Panels

It was necessary to use veneers that were closely matched in strength so that all strength differences in the glued specimens would reflect only the influence of the laminating process. Only clear, tight, straight-grained veneer was accepted. Since density is the most reliable index of the strength of clear wood, all sheets were of matched specific gravity based on oven-dry weight and volume. This was accomplished as follows:

1. The veneer, conditioned to 8 percent moisture content, was precisely cut to 11- by 11-inch sheets.
2. The average thickness of each sheet was determined to 0.0005-inch accuracy.
3. Each sheet was weighed to 0.01-gram accuracy.
4. The oven-dry weight was determined by dividing the weight at 8 percent moisture content by 1 plus the moisture content expressed as a decimal (1 + .08).
5. The oven-dry volume was determined from the 8 percent moisture content volume by subtracting the theoretical weight loss in grams from 8 percent moisture content to oven dry. (The assumption that the volumetric shrinkage of yellow-poplar below fiber saturation point is equivalent to the volume of moisture lost was experimentally tested and found to be without significant error.)
6. Specific gravity based on oven-dry weight and volume was conveniently expressed in terms of weight and volume at the given moisture content by the following equation:

$$SG = \frac{V + MC(V - W)}{W}$$ in which,

Equation 1

SG = Specific gravity, oven-dry weight, oven-dry volume basis
W = Weight in grams at the given moisture content (8 percent)
MC = Moisture content (8 percent)
V = Volume in cubic centimeters at the given moisture content (8 percent).

Panels were assembled from sheets of veneer averaging 0.46 in specific gravity.

Panels assembled from 1/10-, 1/20-, 1/40- and 1/60-inch veneer consisted of 3, 7, 13, and 17 laminations respectively. The phenol-resorcinol formaldehyde adhesive, Penacolite G-1215, manufactured by Koppers Company, Inc., was used in accordance with recommendations of the manufacturer. Spreads equivalent to 45 pounds per 1,000 square feet of glue line were employed. Panels were hot pressed for 10 minutes at 200° F. with 150 psi. pressure. After removal from the hot press, all panels were conditioned for one week in a humidity cabinet controlled at 100° F. and 12 percent equilibrium moisture content conditions.

Preparation of Specimens

Two 1- by 10-in. beams and two .625- by 10-in. tension blanks, all of panel thickness, were randomly selected from each panel. Tension blanks were shaped into specimens which were proportionately patterned after that described in A.S.T.M. Designation D 805-47 *(1)*. A template was used to guide the blank against the cutter head of a jointer to insure precise and uniform machining. Prior to testing, all specimens were conditioned to uniform weight under 12 percent equilibrium moisture content conditions.

Procedure of Testing

All specimens were tested on a Baldwin Southwark, hydraulically-operated testing machine provided with two accurate low-load ranges. Loads supported by beams were measured to 0.2-pound accuracy with a scale range

of 240 pounds and those resisted by tension specimens were measured to 1-pound accuracy with a scale range of 1,200 pounds.

The small beams were supported on sensitive, self-aligning knife edges and were center-loaded in a direction normal to the glue line with a bearing block meeting A.S.T.M. specifications. The rate of loading was calculated to produce a maximum fiber strain of 0.0015 in. per in. per min. Deflections under the load were taken to failure to 0.001-in. accuracy with an Ames dial. Span-depth ratios of 27 to 1 were maintained throughout. The specific gravity of each beam was determined following the test.

TABLE 1.—STRENGTH PROPERTIES OF PHENOL-RESORCINOL-FORMALDEHYDE GLUED, YELLOW POPLAR LAMINATES

		Bending strength					Tensile strength
Specimen	Specific gravity	Fiber stress at proportional limit	Modulus of rupture	Modulus of elasticity	Work to proportional limit in-lb. per cu. in.	Work to maximum load in-lb. per cu. in.	Maximum tensile strength
		psi.	psi.	1,000 psi.			psi.
1/10-1-1	.48	7,570	14,300	1,780	1.20	13.80	17,900
1/10-1-2	.50	6,860	12,500	1,680	1.20	10.21	17,200
Ave. 1/10-1	.49	7,215	13,400	1,730	1.22	12.00	17,550
1/10-2-1	.49	7,020	11,500	1,640	1.33	8.48	17,100
1/10-2-2	.51	7,650	13,000	1,760	1.41	13.20	19,200
Ave. 1/10-2	.50	7,335	12,250	1,700	1.37	10.84	18,650
1/10-3-1	.56	7,180	13,300	1,820	1.25	12.02	13,400
1/10-3-2	.54	7,160	12,300	1,580	1.42	10.12	16,800
Ave. 1/10-3	.55	7,170	12,800	1,700	1.34	11.07	15,100
AVE. 1/10	.51	7,240	12,810	1,710	1.31	11.30	17,100
1/20-1-1	.63	7,950	12,900	1,940	1.44	7.14	16,100
1/20-1-2	.60	7,600	12,700	2,010	1.27	7.50	16,400
Ave. 1/20-1	.615	7,775	12,800	1,985	1.35	7.32	16,200
1/20-2-1	.62	8,000	12,700	1,980	1.43	9.52	17,100
1/20-2-2	.63	7,770	12,400	1,950	1.40	8.32	17,600
Ave. 1/20-2	.625	7,885	12,550	1,965	1.42	8.95	17,300
1/20-3-1	.57	7,200	11,800	1,820	1.27	7.76	15,200
1/20-3-2	.60	7,950	13,100	1,760	1.60	8.30	17,100
Ave. 1/20-3	.585	7,575	12,450	1,790	1.64	8.02	16,650
AVE. 1/20	.61	7,745	12,600	1,913	1.47	8.10	16,730
1/40-1-1	.69	7,550	12,100	1,920	1.33	7.03	20,000
1/40-1-2	.73	6,500	13,100	2,050	.92	10.66	19,300
Ave. 1/40-1	.71	7,025	12,600	1,985	1.13	8.85	19,650
1/40-2-1	.72	6,800	12,900	1,820	1.13	11.42	18,600
1/40-2-2	.72	7,670	13,100	2,100	1.25	8.30	21,000
Ave. 1/40-2	.72	7,235	13,000	1,960	1.19	9.86	19,800
1/40-3-1	.72	7,000	12,500	2,040	1.07	8.20	20,200
1/40-3-2	.76	8,180	14,100	2,090	1.41	11.77	19,500
Ave. 1/40-3	.74	7,590	13,300	2,065	1.24	9.98	19,850
AVE. 1/40	.72	7,280	12,970	2,005	1.19	9.56	19,770
1/60-1-1	.85	7,870	14,300	2,180	1.21	15.00	22,400
1/60-1-2	.82	6,830	13,200	1,970	1.29	12.05	23,100
Ave. 1/60-1	.835	7,350	13,750	2,075	1.25	13.53	22,750
1/60-2-1	.84	7,700	14,000	2,050	1.29	13.05	21,000
1/60-2-2	.81	7,070	12,600	1,910	1.18	11.00	22,300
Ave. 1/60-2	.825	7,385	13,300	1,980	1.24	12.03	21,650
1/60-3-1	.87	7,570	12,200	2,100	1.23	10.70	21,400
1/60-3-2	.86	7,050	13,400	2,120	1.04	10.77	19,300
Ave. 1/60-3	.865	7,310	12,800	2,110	1.14	10.74	20,350
AVE. 1/60	.84	7,270	13,280	2,055	1.21	12.10	21,580

Tension specimens were supported in Templin grips and loaded to failure at a rate of 0.07 in. per min. The increase in rate of loading over that specified in A.S.T.M. Designation D 805-47 was found to have no significant effect on maximum tensile strength values.

Results

The results of standard tests including properties of individual specimens and averages for each panel and for laminates of each veneer thickness are presented in Table 1. Test specimens are identified with veneer thickness, panel number and sample number. The sample numbers of bending and tension specimens are independently assigned. The specific gravity of each beam is given and the average of the two values is considered the average of the panel. The static bending properties, fiber stress at proportional limit, modulus of rupture, modulus of elasticity, work to proportional limit, and work to maximum load, and the tension strength property, maximum tensile strength, are tabulated.

Discussion of Results

Specific Gravity

The specific gravity of a casting of the polymerized adhesive was found to be 1.25. As logically antipicated, the specific gravity of the laminates increased materially with decreasing veneer thickness. In order to interpret intelligently the results of mechanical testing, it is of importance to distinguish between the increase in specific gravity resulting from addition of resin and that resulting from compression of the wood in gluing. Knowing the total unpressed thickness of the veneer in each assembly, the thickness of the pressed assembly, and the average thickness of the adhesive layers between veneers, the total percent of compression could be closely estimated. For these computations the liberal value for average glue-film thickness of 0.002 in. was used. Table 2 presents a summary of factors influencing the specific gravity of the pressed panels.

The trend of increasing compression with increasing number of glue lines per unit of panel thickness is of significance. It is recognized that wood is appreciably plasticized with impregnating resins *(14)* and that thin veneers in combination with Tego film can be readily compressed *(12)*. The foregoing data indicate a similar plasticizing effect imparted by a phenol-resorcinol-formaldehyde resin. Therefore, it is to be expected that the increase in density is largely associated with the degree of penetration of the resin and is not of uniform occurrence throughout the cross section of the laminate. This is supported by the compressed and distorted appearance of the rays in the vicinity of the glue line (Fig. 1).

Tensile Strength

In *Technologie des Holzes (7)*, Kollmann states that the adhesive makes an important contribution to the tensile strength of plywood, dependent upon the extent of glue penetration. He does not, however, elaborate upon this statement except to point out that maximum tensile strengths are attained when very thin veneers are glued with synthetic resins. This increase in strength is attributed to the fact that the adhesive minimizes shearing failures which result in long-fibered, or splintering, tension failures. Thus, in veneer into which the glue has penetrated, the intrinsic tensile strength of the wood fiber is more nearly approached.

The theory advanced by Kollmann is strongly supported by the results of tension tests of laminated yellow-poplar veneer in the present study. A trend of increase in strength accompanies the decrease in veneer thickness from laminates of 1/20-in. to 1/60-in. veneer. Laminates of 1/10- and 1/20-in. veneer have similar strength properties. A statistical analysis of variance *(15)* significantly separates the 1/10- and 1/20-in. veneer classes from the other two. The analysis shows an 80-percent probability of the 1/60-in.

TABLE 2.—SUMMARY OF FACTORS CONTRIBUTING TO PANEL SPECIFIC GRAVITY

Nominal veneer thickness in.	Average initial thickness of veneer in.	Percent wt. of dry resin based on o.d. wt. of wood	Percent compression	Specific gravity of assembly	Computed ave. specific gravity of wood in assembly
1/10	.0967	7.5	2.5	.51	.47
1/20	.0491	19.4	5.7	.61	.49
1/40	.0246	41.5	10.2	.72	.51
1/60	.0174	60.0	14.5	.84	.53

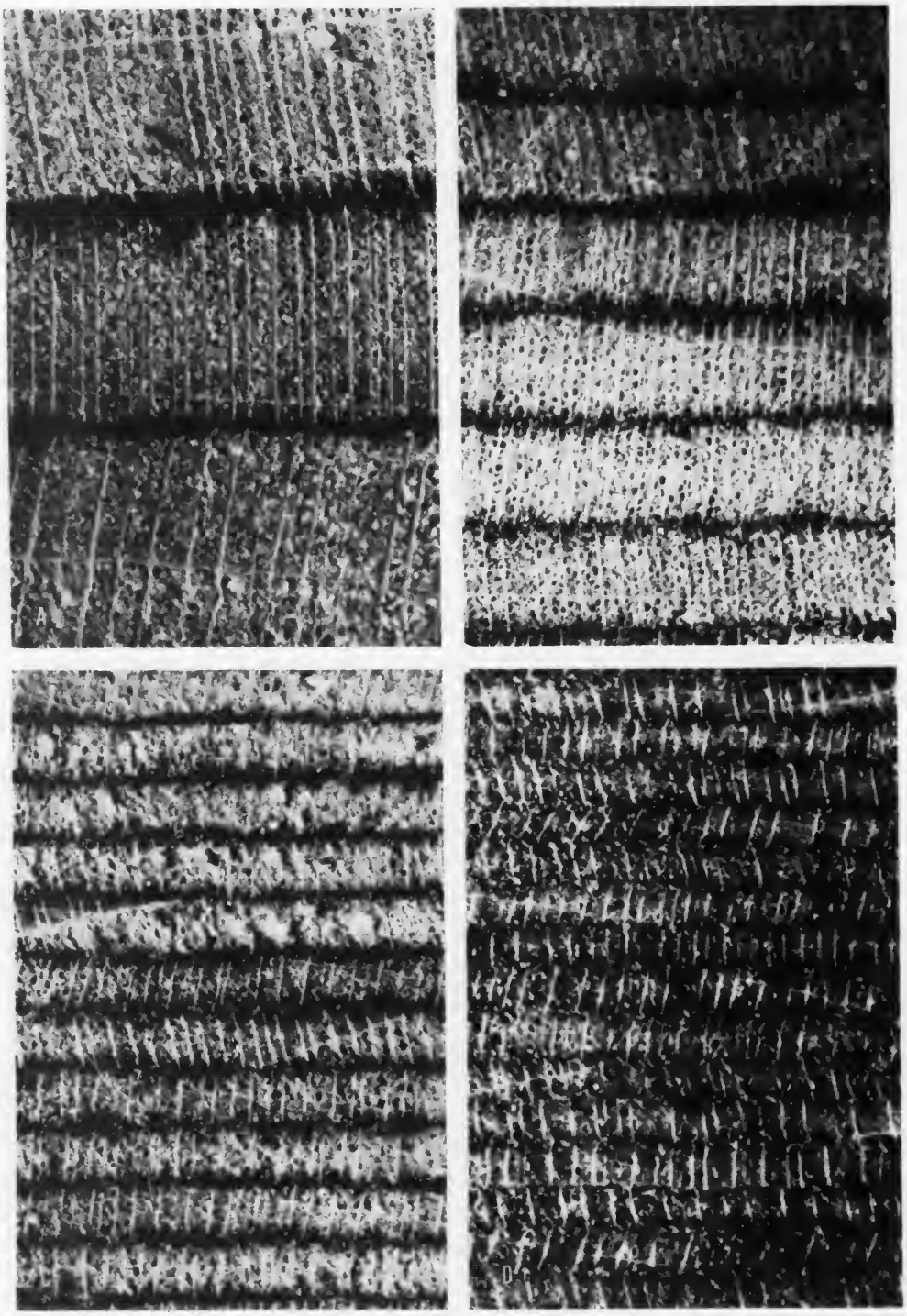

Fig. 1.—Cross sections, enlarged to 15 diameters, of laminates made with various thicknesses of veneer. (A) 1/10-inch. (B) 1/20-inch. (C) 1/40-inch. (D) 1/60-inch.

veneer laminate being stronger than the 1/40-in. It is believed that significance at the 95-percent level between these two would result from a greater number of tests.

Since sufficient tensile strength data for yellow-poplar are not available for accurate computations of strength-specific gravity relationships, it is assumed for the purpose of comparison that tensile strength is a rectilinear function of specific gravity within the range represented by the wood in the pressed panels. Table 3 shows a comparison of actual and theoretical tension values. The strength of 1/10-in. veneer laminates is assumed to be unaffected by the adhesive and is used as a base for specific gravity corrections.

It may be observed from Table 3 that specific gravity increases can account only for 7.8 and 12.9 percent strength increases above that for the 1/10-in. laminate for 1/40- and 1/60-in. laminates respectively, while the actual increases were 15.6 and 26.2 percent respectively. The tensile strength of the adhesive itself can be assumed to be similar to that of a cast, cellulose-filled phenolic molding powder which is but 6,500 to 9,500 pounds psi. *(13)*. An increase in tensile-strength values of a wood-resin system above the strength of either component is therefore apparent.

TABLE 3.—A COMPARISON OF TENSILE STRENGTH VALUES FROM TESTING WITH THEORETICAL VALUES OF SIMILAR MATERIAL INFLUENCED ONLY BY SPECIFIC GRAVITY CHANGE

Veneer thickness in.	Specific gravity of compressed veneer	Theoretical tensile strength psi.	Actual tensile strength psi.
1/10	.47	17,100	17,100
1/20	.49	17,800	16,730
1/40	.51	18,550	19,770
1/60	.53	19,300	21,580

Examination of the types of failures resulting from stresses in tension (Fig. 2) indicates this increase in tensile strength may be partially attributed to the development of the inherent strength of the wood fibers. Laminates of 1/10- and 1/20-in. veneer exhibited a shearing type failure, indicating a separation of fibers in longitudinal planes of least resistance, while the 1/40- and the 1/60-in. veneer laminates showed increasingly more nearly transverse failures. Failures of the 1/60-in. veneer specimens were essentially perpendicular to the direction of applied stress.

Fig. 2.—Typical tension failures in laminates made with various thicknesses of veneer. (A) 1/10-inch. (B) 1/20-inch. (C) 1/40-inch. (D) 1/60-inch.

Bending Strength

The only bending property that reflects a definite influence of the laminating process is modulus of elasticity or Young's modulus. Moduli of elasticity, presented in Table 1, clearly increase with decrease in thickness of the laminae. The trend is confirmed by a statistical analysis of variance *(15)* which indicates that 1/10-in. veneer laminates are significantly lower in modulus of elasticity than the other three classes and that 1/20-in. veneer laminates are significantly lower than 1/60-in. It is indicated that the change in elastic properties is not sufficiently pronounced to be positively reflected in differences between all veneer thickness classifications.

If the increase in density resulting from compression were uniform throughout the cross section of the beam, the increase in modulus of

elasticity could not satisfactorily be explained by this alone. Table 4 compares moduli of elasticity determined from testing with values computed by correcting the average value of the 1/10-in. veneer laminates for the increase in veneer specific gravity resulting from compression. The accepted exponential relationship *(4)*.

$$\frac{E}{E'} = \frac{G}{(G')}\,1.25, \text{ in which} \qquad \text{Equation 2}$$

E = Modulus of elasticity at specific gravity, G and

E′ = Modulus of elasticity at specific gravity G′ was used.

Table 4.—A Comparison of Modulus of Elasticity Values from Testing with Theoretical Values For Similar Material Influenced Only by Specific Gravity

Veneer thickness in.	Veneer specific gravity	Theoretical modulus of elasticity 1,000 psi.	Actual modulus of elasticity 1,000 psi.
1/10	.47	1,710	1,710
1/20	.49	1,800	1,913
1/40	.51	1,890	2,005
1/60	.53	1,985	2,055

It is apparent from the foregoing table that specific gravity influences account for 5.25, 10.5 and 16.0 percent increases in Young's modulus for the 1/20-, 1/40-, and 1/60-in. veneer laminates respectively, and respective increases were determined through tests to be 10.9, 17.3 and 20.2 percent. Although the improvement in modulus of elasticity, which cannot be attributed to specific gravity increase, is not as pronounced as that shown by tensile strength, the data strongly indicate an additional influence of factors other than veneer compression.

Published data *(13)* indicate that the modulus of elasticity of the adhesive does not exceed 1,100,000 psi. Therefore, it can contribute to improvement of the elastic modulus of a laminate only as a result of impregnation into the cell cavities, or as a result of combination with the cell wall to form an amalgam with properties differing from those of its components. In either event, additional stiffness can be attributed only to that portion of the veneer into which the adhesive has penetrated. It obviously follows that a laminate is a material of composite cross section, the components of which exhibit materially different elastic properties.

When a material is stressed in flexure it is recognized that tensile, compressive, and shearing stresses are operative *(8 16)*. The magnitude and consequent importance of shearing strains in a rectangular beam are contingent upon the ratio of span to depth, the type of loading, and the modulus of rigidity in a plane parallel to the neutral axis. Since shearing deformations are reflected in beam deflections, a working knowledge of the extent of this effect is important in precise design techniques.

Timoshenko *(16)* has shown that additional deflections resulting from shearing strains in a cantilever beam can be determined from strain-energy relationships and that the modified equation for the determination of bending deflections becomes

$$a = \frac{PL^3}{3EI}\left(1 + \frac{3}{10}\left(\frac{h^2}{L}\right)\frac{E}{G}\right), \text{ in which} \qquad \text{Equation 3}$$

a = total deflection

P = load, pounds

L = span

h = depth

E = modulus of elasticity

I = moment of inertia about the neutral axis

G = modulus of rigidity.

It is further shown by Timoshenko that the deflection of a simple beam can be most accurately computed by treating the beam as two cantilever beams loaded by the reactions.

The effective modulus of elasticity of a cantilever beam with a given span-depth ratio is expressed by the equation, $E' = \frac{PL^3}{3aI}$. The relationship of the true modulus of elasticity to the experimentally determined value is expressed by equation, $E = E'\ 1 + \left(\frac{3}{10}\left(\frac{h^2}{L}\right)\frac{E}{G}\right)$. The magnitude of the discrepancy between experimental and true modulus of elasticity values is dependent upon the square of the span-depth ratio and the modulus of rigidity. Materials with a high ratio of modulus of elasticity to modulus of rigidity exhibit important differ-

ences in effective moduli of elasticity at different span-depth ratios. Since the modulus of rigidity of wood in a direction parallel to the fibers is but .05 to .07 Young's modulus *(3)*, shearing deformations in beams of practical lengths and depths are often significant.

The modulus of elasticity of a material of homogeneous cross section, as determined from compression or tension, is closely approximated by that determined from bending a simple beam with an infinite span-depth ratio. Therefore, in the case of solid wood, the modulus of elasticity in pure bending is approximately the same as that in compression. In the material of composite cross section, such as plywood or laminated wood where the layers of different elastic properties are parallel to the neutral plane, the pure modulus of elasticity in bending differs appreciably from that in tension or compression *(4)*. This difference is explained by the fact that the strain throughout the cross section of a column is uniform and all layers of similar elasticity are equally stressed, but the strain of each layer paralleling the loaded face of a beam varies with its distance from the neutral plane; consequently, the stress differs with position of the layer as well as its elasticity. The elasticity of a beam of composite cross section is expressed by the equation *(4)*,

$$E = \frac{1}{I}\sum_{i=1}^{i=n} E_i I_i \text{ in which}$$

Equation 4

E = elastic modulus of beam
I = moment of inertia
E_i = elastic modulus of ith layer
I = moment of inertia of ith layer

and that of a column of composite cross section is expressed by the equation *(4)*,

$$E = \frac{A}{1}\sum_{i=1}^{i=n} E_i A_i \text{ in which}$$

Equation 5

E = elastic modulus of column
A = cross-sectional area
E_i = elastic modulus of ith layer
A_i = cross-sectional area of ith layer

In the case of a veneer laminate in which the areas of high modulus of elasticity are concentrated at the glue line, the pure Young's modulus determined from bending can be expected to be less than that determined from tension or compression.

For many species of solid wood, either deflections or elasticity values at any span-depth ratio can be readily computed since moduli of rigidity and elasticity are both available. Work at the Forest Products Laboratory has demonstrated the effectiveness of the consideration of shearing deformation in deflection computations *(10)*. However, in the case of plywood or laminated wood effective modulus of rigidity is not clearly established and modulus of elasticity in bending is not comparable with that in compression. Unless these variables can be ascertained, the utility of Young's modulus determined from bending at a given span-depth ratio is narrowly limited.

The equation, $E' = \dfrac{E}{1 + \frac{3}{10}\left(\frac{h^2}{L^2}\right)\frac{E}{G}}$ expresses modulus of elasticity of a cantilever beam as a hyperbolic function of the square of the depth-span ratio. The curve of modulus of elasticity in bending approaches that devoid of shearing influences as an asymptote parallel to the x-axis. The equation remains valid for a simple beam if the square of one-half of the depth-span ratio is substituted.

A linear transformation of a hyperbolic relationship can be made by expressing $\frac{x}{y}$ as a function of x. This specific hyperbola may be transformed by the following steps:

$$E' = \frac{E}{1 + \frac{3}{10}\left(\frac{\frac{h^2}{L}}{2}\right)\frac{E}{G}}$$

1. $\dfrac{\frac{h^2}{L^2}}{\left(\frac{2}{2}\right)} = \dfrac{1}{\left(\frac{L^2}{2}\right)}$ expression of depth-span ratio as fraction with unit numerator

2. $E' = \dfrac{E}{1 + \frac{.3}{\left(\frac{L^2}{2}\right)}\frac{E}{G}}$

$= \dfrac{E}{\frac{\left(\frac{L^2}{2}\right)G + .3E}{\frac{L^2}{2}G}}$ simplification

3. $\frac{L^2}{\left(\frac{2}{E'}\right)} = \frac{\left(\frac{L^2}{2}\right)G + .3E}{GE}$ transposition to rectilinear form

4. $\frac{L^2}{\frac{2}{E'}} = \frac{.3}{G} + \frac{1}{E}\left(\frac{L^2}{2}\right)$ simplification

Equation 4 is a simplified rectilinear form of the hyperbola. The term, $\frac{.3}{G}$, is graphically represented by the intercept of the curve with the y-axis, and the asymptote parallel to the x-axis or pure modulus of elasticity in bending is the reciprocal of the slope. This relationship should provide an indirect method of determining both modulus of rigidity and modulus of elasticity in pure bending.

In order to confirm this theory and to determine variables necessary for the computation of modulus of elasticity values for any desired span-depth ratio, additional mechanical tests were necessary. One beam was taken from the remaining portion of two panels of each veneer thickness. In addition, two control beams of solid wood with a specific gravity value of 0.47 were selected for comparison. The beams were conditioned to approximately 10 percent moisture content prior to testing. Each was then loaded as a simple beam with span-depth ratios of 26/1, 22/1, 18/1, and 14/1, sufficient deflections being taken to 0.0001 inch accuracy during each loading to establish stress-strain relationships. At no time was proportionality exceeded. Since the influence of variable overhang on shearing deformations in this type of material had been previously proven insignificant, beams were not reduced in length after each loading. Modulus of elasticity values were computed for each condition of loading by the conventional equation $E = \frac{PL^3}{4abd^3}$ in which the previously unidentified symbols b and d are respectively the width and depth.

Table 5 presents a summary of the data thus collected.

The data presented in the foregoing table were found to closely approximate the theoretical hyperbolic trend as illustrated in Fig. 3. A linear transformation of the data obtained for each specimen was made by balancing a straight line through the points resulting from plotting the quotient of one-half of the square of the span-depth ratio divided by the effective modulus of elasticity over one-half of the square of the span-depth ratio (Fig. 4).

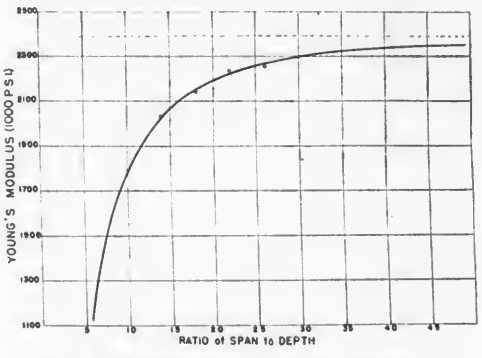

Fig. 3.—Relationship of Young's modulus to span-depth ratio.

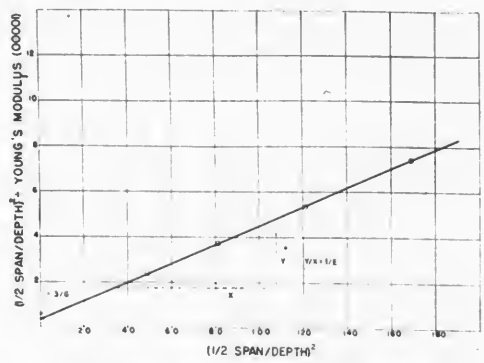

Fig. 4.—Linear transformation of hyperbolic trend (Fig. 3).

TABLE 5.—THE INFLUENCE OF SPAN-DEPTH RATIO ON EFFECTIVE MODULUS OF ELASTICITY

Span-depth ratio	Specimen No.[1] 1/10—1	1/10—2	1/20—2	1/20—3	1/40—1	1/40—2	1/60—2	1/60—3	Control 1	Control 2
	Modulus of elasticity 1,000 psi.									
26-1	1,545	1,790	2,090	1,990	2,330	2,210	2,260	2,280	1,440	1,520
22-1	1,520	1,790	2,080	1,860	2,250	2,190	2,240	2,170	1,420	1,490
18-1	1,420	1,720	1,920	1,750	2,100	2,150	2,140	2,100	1,400	1,480
14-1	1,370	1,570	1,660	1,420	2,040	1,900	2,030	1,820	1,290	1,390

[1]Specimens are identified by the veneer thickness and the number of the panel from which they were taken.

For each specimen, the modulus of rigidity was determined from the intercept and the pure modulus of elasticity from the reciprocal of the slope. The modulus of elasticity thus determined should be that approached by a beam with an infinite ratio of span to depth.

In order to confirm the asymptote elasticity values and thereby validate the method of making adjustments for horizontal shearing influences, a simple, direct method of determining a pure modulus of elasticity in bending was desired. Horizontal shearing stresses resist vertical-force couples which result from the changing magnitude of bending moments along the span. Shearing stresses are nonexistent between the loads of a beam loaded at third points, since the bending moment is constant in this portion of the span. Consequently the deflection between the loads results from deformation in pure bending. By the principles of area-moments *(8)*, the difference between the maximum deflection and that under either load may be determined. The equation, $a = \frac{Pl^3}{36Ebd^3}$, in which a is the difference between the maximum deflection and the deflection under either load and P is the total load, is a simplified expression derived by this method. Thus, Young's modulus (E) can be computed after the experimental determination of a.

Each beam, for which the hyperbolic relationship of elasticity and span-depth had been determined, was loaded at third points within its proportional limit three times. During successive loadings, deflections were taken to 0.0001-inch accuracy under the center of the beam and under each load. The difference between deflection of mid-span and the average of the deflections at the load points was used as a in the determination of Young's modulus, which is the pure modulus of elasticity in bending and is theoretically comparable to the asymptote of the previously established hyperbola.

Table 6 shows a comparison between asymptote values and modulus of elasticity values determined from third-point loading. Data presented in this table show a close similarity between elasticity values determined from direct and theoretical methods. Discrepancies, with the exception of one control beam, do not exceed three percent of the directly determined values, thus establishing the validity of the application to glued wood of strain-energy relations described by Timoshenko *(16)*.

The modulus of rigidity values determined from the intercepts of the linearly transformed hyperbolas are the effective moduli of the various composite cross sections tested. Complex differences resulting from adhesive concentration, lathe checks, etc. undoubtedly exist be-

TABLE 6.—A COMPARISON OF ELASTIC-PROPERTY VALUES DETERMINED BY DIRECT AND INDIRECT METHODS

Specimen	Modulus of elasticity from asymptote of hyperbola 1,000 psi.	Modulus of elasticity from third-point loading 1,000 psi.	Discrepancy based on E from third-point loading percent	Modulus of rigidity from intercept psi.
1/10-1	1,640	1,685	+2.7	43,000
1/10-2	1,910	1,900	— .5	58,000
Ave.	1,775	1,790	+ .84	50,500
1/20-2	2,260	2,210	—2.3	25,000
1/20-3	2,300	2,270	—1.3	50,000
Ave.	2,280	2,240	—1.8	37,500
1/40-1	2,500	2,540	+1.6	60,000
1/40-2	2,310	2,370	+2.5	94,000
Ave.	2,405	2,455	+2.2	77,000
1/60-2	2,390	2,320	—3.0	80,950
1/60-3	2,460	2,470	+ .45	50,000
Ave.	2,425	2,395	—1.25	65,475
Control 1	1,490	1,570	+5.1	75,000
Control 2	1,550	1,600	+3.1	100,000
Ave.	1,520	1,585	+4.1	85,000

tween different planes paralleling the loaded face. The variability of modulus of rigidity values shown in Table 6 is therefore not unreasonable.

A statistical analysis of variance shows no significant differences between modulus of rigidity values for laminates of different veneer thickness. This indicates that the most accurate expression of elasticity in shear for any veneer thickness is the mean of all values obtained, which proved to be 57,620 psi. An average modulus of 85,000 psi. was determined for the solid wood controls. Tests at the Forest Products Laboratory *(3)* indicated no correlation between modulus of rigidity and specific gravity, and provided an average value of 97,000 psi. for solid yellow-poplar wood in the longitudinal-tangential plane at a moisture content of approximately 11 percent.

By using the average effective modulus of rigidity in the Equation 13, the pure Young's modulus for each veneer thickness class can be computed from data presented in Table 1. The effective elasticity values to be anticipated at any span-depth ratio can then be determined. The effect of span-depth ratio on Young's modulus in bending is graphically illustrated in Fig. 5.

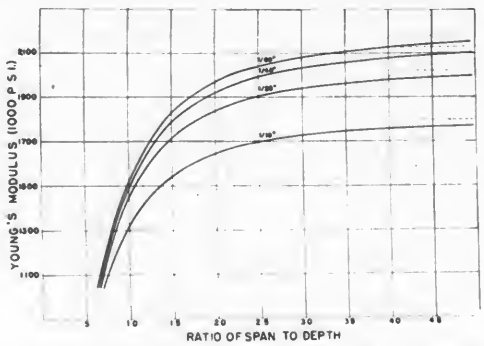

Fig. 5.—Comparison of the effect of span-depth ratio on Young's moduli of 1/10-, 1/20-, 1/40-, and 1/60-inch veneer laminates.

The data obtained from beam tests indicate a definite correlation between the thickness of veneer laminae and Young's modulus. Within the limits of this study, a hyperbola accurately expresses Young's modulus as a function of the number of uniformly spaced glue lines per inch of panel depth. The elasticity attained with infinitely thin laminations is approached as an asymptote. This relationship is represented by a graph established by the method of least squares (Fig. 6)' from which the pure Young's

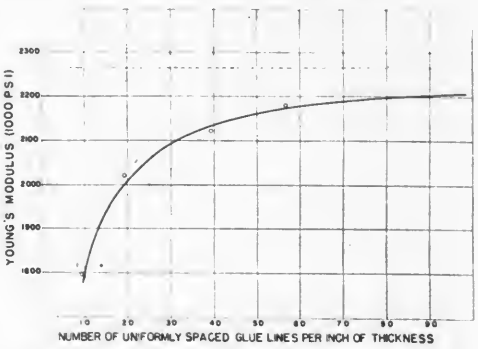

Fig. 6.—Relationship of Young's modulus to the number of uniformly spaced glue lines per inch of laminate thickness.

moduli in bending can be determined for laminates of any desired veneer thickness below the maximum thickness studied. This value, in turn, can be used to predict the elasticity or deflection of a simple beam with any desired span-depth ratio.

Although the information obtained by this investigation applies specifically only to material similar to that tested, the fundamental principles evolved undoubtedly influence the properties of all veneer-resin systems. Similar or greater influences of the adhesive may be expected in the case of plywood. Further, horizontal shearing deformations are more important in plywood beams because of the low modulus of rigidity in the radial-tangential plane. Additional research utilizing principles and techniques established by this investigation should lead to information requisite to more refined design methods.

Summary

An investigation was undertaken to determine fundamental differences in strength properties between veneer laminates and solid wood. The study was limited to strength properties of yellow-poplar veneer laminates bonded with a phenol-resorcinol-formaldehyde adhesive. Laminates composed of 1/20-, 1/40-, 1/60- and 1/80-inch laminae were compared.

A decrease in the thickness of laminae resulted in an increase in compression and consequent increase in the specific gravity of the assembled veneer.

Tensile strength of 1/40- and 1/60-in. veneer laminates was improved 15.6 and 26.2 percent respectively over that of 1/10-in. Specific gravity influences can account for but one-half of this increase. The nature of the failures of 1/40- and 1/60-in. veneer laminates indicates a closer approximation of the intrinsic fiber strength.

Modulus of elasticity was the only flexural strength property improved by lamination. A hyperbolic trend of increase accompanied a decrease in thickness of laminae. Properties and theory indicate that a laminate of thin veneer is a material of composite cross section, the modulus of elasticity of which differs in compression and bending.

Using equations established from the theory of strain-energy in bending. Young's modulus was found to be a hyperbolic function of the square of one-half the ratio of span to depth. Moduli of rigidity and elasticity were theoretically determined.

Young's modulus, devoid of shearing deformations, was directly determined from the difference in deflections at mid-span and at the points of loading in a third-point loaded beam. The pure modulus of elasticity established by this direct method was found to be closely comparable to that computed from the hyperbolic trend of the effective modulus of elasticity values at various span-depth ratios.

The results of this investigation indicate that, through an expansion of theories and techniques which have been found valid in this study, the effect of the fundamental glue-line properties on the strength of veneer laminates can be clearly established and that improvement of properties imparted to veneer by lamination can be advantageously considered in the efficient use of veneer-resin systems.

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Discussion

Mr. R. M. Melrose (F. S. Harmon Mfg. Co.): Was there a difference in trends shown by the different glues?

Mr. Preston: Inasmuch as spreads recommended by the manufacturers were used and were not comparable in all cases, all adhesives cannot be directly compared. It appears, however, that phenolic and resorcinol resins impart a greater improvement in properties than the urea resin used.

Dr. H. D. Erickson (Assoc. Prof. of Forest Products, University of Washington): In your studies you obtained appreciable penetration of the glue into the veneer. What results would you expect using a wood which was not penetrated by the glue but still obtaining some wood compression?

Mr. Preston: From all indications, the improvement in properties is largely associated with the extent of adhesive penetration. Inasmuch as compression increases with decrease in veneer thickness, it also appears to accompany penetration. Therefore, I should expect the properties of a wood which resisted penetration to be enhanced to a lesser extent.

Mr. E. J. Reichman (Simpson Logging Co.): Your quoted value for strength of a glue line was that for a plastic or moulded material, was it not?

Mr. Preston: Yes.

Mr. Reichman: Was your work with laminates of veneer with the grain parallel? Have you applied your method of determining modulus of elasticity to cross banded materials, or laminates of different material?

Mr. Preston: The phase of the work covered by this paper includes only the properties of laminated wood assembled with one adhesive. Similar tests are being conducted on conventional plywood of yellow poplar veneer. The results of this phase have not as yet been analyzed. When the work is complete, I would be pleased to furnish you with the information that is gained.

Mr. A. C. Horner (Timber Engineering Co.): What method is used in determining the modulus of elasticity for glue?

Mr. Preston: The modulus of elasticity of the adhesive was assumed to be similar to that of a cast, cellulose-filled phenolic molding powder and published data were accepted.

The Place of Water-Repellent Preservatives in Forest Products

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Water-repellent toxic preservative solutions have been in commercial use in the millwork industry since about 1931, and by 1936 their use was beginning to spread rapidly through the millwork jobbers, and a few of the stock mills were using this type of treatment in a limited way. In 1938 the National Door Manufacturers Association (now known as the National Woodwork Manufacturers Association) formed an advisory committee that set up standards for treating solutions used in treating millwork. This committee meets each year at the U. S. Forest Products Laboratory, Madison, Wisconsin. Through their guidance the treatment of millwork has grown to a point where most millwork plants consider it a standard practice today.

Introduction

SINCE the beginning of time, wood has been one of the leading building materials, but like all things it has its shortcomings. It will decay and stain if the moisture content is high enough. It also swells when it gets wet, and shrinks when it dries out, with frequent warping and checking.

A water-repellent preservative is not a cure-all, but there are a great many applications where from a practical standpoint it overcomes these shortcomings of wood. Back in 1938 the National Door Manufacturers Association (now known as the National Woodwork Manufacturers Association) formed what is known as the National Woodwork Manufacturers Association Advisory Committee. It is made up of men and women from laboratories throughout the country who have carried on research in the field of wood preservation. This group has set up standards to guide and protect the millwork industry. During World War No. 2 many branches of the Government made use of the standards set up by this group, to guide them in their wood-treating problems where a water-repellent preservative was needed.

At the time this Advisory Committee was established, a few of the stock mills and a number of millwork jobbers were treating with a water-repellent preservative in a limited way, and were finding in actual practice that the treatment was reducing the complaints formerly received when their stock was untreated.

To date the solutions which have passed the toxic standard set up by this Advisory Committee contain 5 percent by weight of either pentachlorophenol, tetrachlorophenol, 2-chlor-orthophenylphenol, or a combination of these toxicants.

The chlorinated phenols themselves do not lend any water-repellency to the treating solution, so that it is necessary to add other materials in order to get a water-repellent effect. Standard test methods for determining water repellency have been set up by the Advisory Committee and will soon be published.

Water-repellent preservatives have petroleum spirits as their carriers. The standard dip time for millwork is three minutes at room temperature. In ponderosa pine sapwood this gives an average penetration of from 1.5 to three inches up the end grain, and $\frac{1}{16}$ to $\frac{1}{4}$ inch side grain.

The effectiveness of water-repellent preservatives in preventing the development of checks and stain in test samples exposed to severe laboratory conditions, consisting of cyclic exposure to wetting and drying, is shown in Fig. 1. The marked contrast between the treated and untreated portions of these test samples, even after such long and severe exposure, demonstrates not only the effectiveness of the treatment, but illustrates a testing technique that can be used by interested individuals or laboratories.

In the beginning, treatment was confined largely to windows and frame. The toxic content protected these items against decay, stain, and insects which attack wood, while the water-repellent phase helped to keep the joints tight and reduce the swelling and shrinking to a point where the windows would work freely, even in wet weather. This dimensional control, of course, reduced checking and warping. Many of the early tests carried out on windows

Fig. 1.—The left half of each of these sections of southern pine (above) and ponderosa pine (below) blocks were treated with a water-repellent preservative solution. The right portions were left untreated. Exposure was made by placing in a rain machine for eight hours, drying, and repeated exposure to the same cycle until 100 hours of exposure in the rain machine had been completed. Note the severe end checking in the untreated portion of the upper board, and heavy blue stain in the untreated portion of the lower board.

were conducted by placing window units out in the weather, having some of the windows properly treated and the rest untreated. After the treatment was dry, the windows would be given three coats of paint on the outside, and two coats of varnish on the inside. A comparison of sash joints at the end of 8.5 years is shown in Fig. 2. This illustrates how a three-minute dip in a good water-repellent preservative can protect sash.

Fig. 2.—The joints of two sash that were mounted in their frames and exposed out in the weather for 8½ years, with two coats of varnish on what would be the inside of the sash, and three coats of lead-in-oil on what would be the outside of the sash. The joint shown at left was given a 3-minute dip in a water-repellent toxic before exposure; while that at right was not treated before finishing. Note how the treatment controlled the swelling and shrinking of the joint, and kept it tight as it should be.

The condition of treated sash as compared to untreated sash was striking at the end of 8.5 years of testing. Fig. 3 shows this comparison.

Fig. 3.—Bottom rail of two different window sash after 8½ years in the weather, with three coats of lead-in-oil on one side, and two coats of varnish on the other, just as it would be in a home. Left, the condition of the sash that was not treated before finishing; Right, the condition of the sash that was given a 3-minute dip in a water-repellent preservative.

Experience soon made it evident that treating just the sash was only half doing the job, and the treating of frames rapidly increased, and decay, such as shown in Fig. 4, could be definitely controlled with the standard three-minute dip.

Fig. 4.—These two window sills have been exposed 8½ years out in the weather. The sill at left was given a 3-minute dip in a water-repellent preservative at the time it was manufactured; the sill at right was not treated. Note the decay that has taken place where the sash rests on the sill.

Another important reason for treating frames was to reduce swelling and shrinking of the joints, because constant swelling would split the dado joint and cause the stock to warp and nails to pull. This would create a loose window, which would rattle in dry weather, and allow the window to leak air and water badly. Fig. 5 shows a comparison between treated and untreated frames, and clearly shows the need for a good water-repellent preservative.

We are all familiar with the excellent insulation value of wood, but we find that when wood becomes wet it loses most of its insulation value, because water is an excellent conductor of heat or cold. A good water-repellent

Fig. 5.—Top, condition of two upper frame corners, the one on the left being an untreated frame, the one on the right a treated frame. Note how the treated frame is tight and sound at the joint, while the untreated frame has come apart, due to swelling and shrinking, and the dado joint is split open, destroying the strength of the joint. Bottom shows the lower corners of an untreated and treated frame after 8½ years in the weather, and here we see the same condition as above.

preservative can help wood retain its natural insulation qualities, and a splendid example of this is shown in Fig. 6, where treated windows under high humidity conditions retained their insulation value, while the joints of untreated windows, even though painted and varnished, lost their insulation value to such an extent that the wood itself became frosty on the inside just as did the glass.

This wet condition in the untreated sash caused the growth of blue-stain so that the untreated windows during the summer in this humidity room turned black at the joints with

Fig. 6.—Two sash which were mounted in the south wall of a room that was maintained at 60 percent relative humidity, and 70° to 80° F., of heat the year around. Top, condition of sash during zero weather. The sash on the left was given a 3-minute dip in a water-repellent preservative before installation; the sash on the right was left untreated. Then these windows were given three coats of lead-in-oil on the outside and two coats of varnish on the inside. Note that the untreated sash absorbed so much moisture at the joint that it lost its insulation value and frosted just like the glass, while the treated sash remained warm and dry. Bottom shows these two sash the following summer. Note that blue stain has developed, where we saw frost on the sash, while the treated sash remains free of any sign of stain or decay. The dots on the sash are copper nails driven into the center of the sash so as to take frequent moisture content readings.

stain, (see Fig. 6) while the treated sash remained free of staining organisms.

Doors too, need a water-repellent preservative, because they tend to swell during wet weather and stick, and in the average home during the winter the inside of the house is much drier than the outside, and this condition many times causes doors to warp. In homes that are humidified the conditions sometimes reverse themselves, so that the inside of the door is exposed to a higher humidity than the outside, and again may create a warped condition. Then too, the swelling and shrinking of the door oftentimes causes checking at the bottom and top of the door. If the door is a panel type, the swelling and shrinking may cause the panels to pull away from the stiles and rails and leave an unpainted line or unvarnished line all around the panel. This is always unsightly.

Because of these conditions, outside doors are being treated today by many manufacturers. Inside doors, cabinet doors, trim, and many other

such items are also being treated. Many homes today have practically all wood in them treated with a water-repellent preservative. The purpose is two-fold. First, it protects the wood in the building while it is being erected. Few houses are ever completed before one or two rainstorms appear, causing the framing or possibly sheathing, sub-floors, joists, and rafters to become wet and swell and shrink. When this type of lumber is treated this action is reduced to a point where rain does practically no harm, and the building process can go on soon after the storm is over. This protection during the building process is especially beneficial to wood siding, as it protects it against rain until the paint can be applied, and should rain come before it is painted, it is just a matter of a few hours after the storm and the painters can go right ahead with the job.

Second, a water-repellent preservative gives the house protection after it is erected, because it protects the wood against excessive swelling and shrinking, as well as decay, stain, and insects which attack wood. We all know that wood when it reaches its fiber-saturation point (which is around 24 percent moisture content) can decay if fungi are present, and when it gets below the fiber-saturation point the fungi lie dormant. Most types of fungi can stay in this dormant stage at least six months and continue to grow again as soon as the lumber reaches the fiber-saturation point. There are some types of fungi that can live as long as three years in dry wood and continue to grow again when a moisture content of 24 to 30 percent or above is reached. Lumber properly treated seldom gets near the fiber-saturation point, and if it does, the toxic content of the treatment protects the wood against fungus growth.

The part of a house that is most apt to show decay first is the wooden porch and steps, as well as the railing and porch posts. It has been found that a water-repellent preservative can greatly reduce the swelling and shrinking of wood in this use, and guard against the buckling, twisting, and checking that occur with the swelling and shrinking of the wood, as well as to protect it against decay and insect attack (see Fig. 7). Small test porches which have been left out in the weather for as long as 12 years, with only a 3-minute dip, are still in good sound condition, whereas untreated porches right beside them have decayed and gone to pieces in four or five years. This does not mean that a 3-minute dip is all that is necessary for this type of exposure, but it does show what even a light treatment can do to protect wood. This same type of protection, of course, is gained on the other wood parts of a home when they are properly treated.

Fig. 7.—Top shows ends of two gum flooring test panels that have been exposed out in the weather one year. The floor on the left was given a three-minute dip in a water-repellent preservative, while the one on the right was left untreated, and both floors were given two coats of floor varnish. Note how the untreated floor has buckled and checked, and distorted the frame, while the treated floor shows little signs of having been exposed for a full year in the weather. Middle shows two small porches exposed out in the weather for 7½ years. The porch on the left was given a 3-minute dip in a water-repellent preservative before exposure; the one on the right was left untreated. Note that the untreated test porch has been practically destroyed, due to decay, while the treated porch is in sound condition. This treated porch is now over 12 years old, and still sound. Bottom shows two oak floors that were fitted tightly together at the time they were made up. The one on the left was given a 3-minute dip in a water-repellent preservative, while the one on the right was left untreated, and then each day for two months eight ounces of water was misted over the top of the varnish. Note how the untreated floor has opened up, due to swelling and shrinking, while the treated floor shows no effect from this repeated wetting.

The treating of the flooring for the interior of a home is growing rapidly, and many homes today are enjoying the protection this type of treatment affords. Not only is the flooring protected against the possibility of decay or termite attack, but it adds a protection against water that cannot be gained in any other way, because we are all familiar with the fact that finishing the floor cannot seal up the cracks

between the floorboards, and when water is tracked in or enters in the form of rain or snow through a window left open, it oftentimes causes the floor to swell and then later to shrink excessively, so as to leave wide, unsightly cracks in the floor (see Fig. 7).

Water-repellent preservative treatments can be very helpful in protecting paint finishes, and especially is this true on siding, trim, and other items of this type.

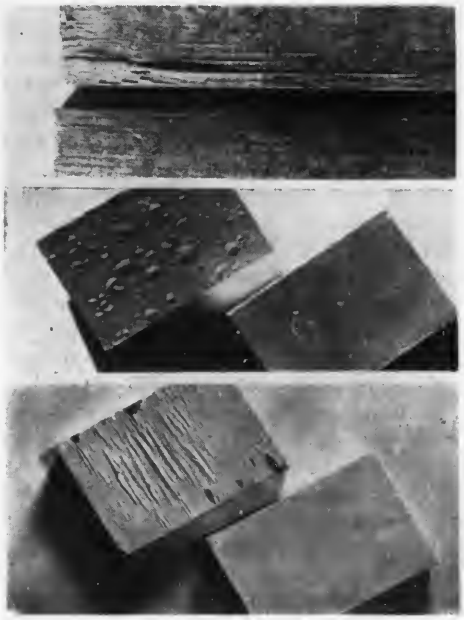

Fig. 8.—Top view, corners of two birch truck body panels after 18 months in the weather. The panel above was untreated and then given two coats of O.D. lusterless enamel as used by our armed forces, and the lower panel was given a 3-minute dip in a water-repellent preservative before finishing. Note how the enamel split and peeled off of the untreated panel, due to water getting in the wood and causing it to swell and shrink, while the preservative protected the treated panel from excessive swelling and shrinking. Middle view, two blocks of pine trim stock that were exposed all winter out in the weather. The panel on the right was given a 3-minute dip in a water-repellent preservative, while the one on the left was left untreated, and then both panels were given two coats of finish. Note how the paint has blistered on the untreated panel, due to excessive moisture in the wood, while the treated panel was protected against this condition. Bottom view, the same two panels as shown in middle, but the photograph was taken the following August after a long dry spell; the untreated panel has dried down, the blisters have become wrinkles, and the paint is peeling off, while the treated panel is still in excellent condition.

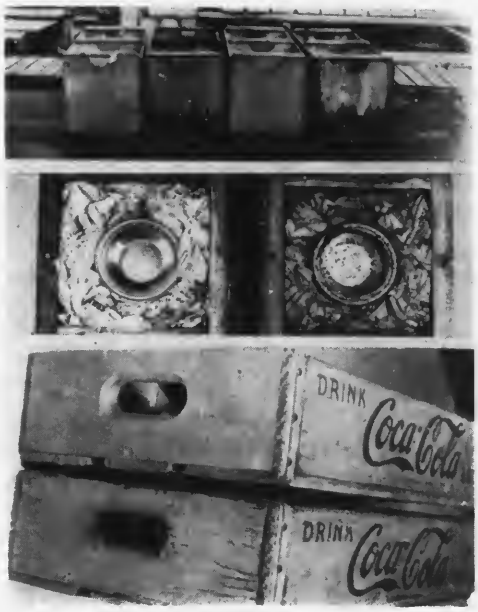

Fig. 9.—Top view, four field boxes used by the canning companies to pick citrus fruit. Boxes Nos. 1 and 3 were given a half-minute dip in a water-repellent preservative, while boxes Nos. 2 and 4 were left untreated. Note how the untreated boxes have absorbed water from the wet platform, while the treated boxes show no sign of moisture absorption. Middle view, two test shipping cases, the one on the left being given a 3-minute dip in a water-repellent preservative, while the one on the right was left untreated. Then each box had a bright tin can placed in the center of it, and packed with common newspaper. These boxes were exposed outside in the weather, and this picture was taken five months after exposure. Note the stain and moisture in the packing paper in the untreated box, and also the rusting of the tin can, while the paper in the treated box is dry and shows no sign of moisture or water, and the can is bright and shiny. Bottom view, two bottle cases after several months of exposure. The top box was given a half-minute dip in a water-repellent preservative, while the bottom box was left untreated. Note how the paint has failed on the untreated box, due to moisture working into the wood, causing swelling and shrinking. This wet condition also causes the nails to rust and the joints of the box to loosen and become wobbly. This condition also invites decay.

We all know that many homes today have humidifiers, so that there is a greater tendency for moisture to work through the walls in the winter. There is also always the possibility of a leak somewhere allowing water and excessive moisture to get behind siding and trim. When this happens, it may cause paint blistering and early paint failure (see Fig. 8).

The idea of back priming on homes has been in use for many years, and the main reason, of course, was to protect the back side of the wood against absorbing excessive moisture, but the use of a water-repellent preservative does a far more effective job, because it not only resists the absorption of water but protects it against decay, stain, and insects as well.

This same degree of protection is imparted to many other items made of wood, such as truck bodies, box cars, roller-coasters in amusement parks, wood fencing, boats, farm buildings, outdoor furniture, and numerous other items made of wood that are exposed to the weather or excessive moisture and water.

The use of a water-repellent preservative in the wood box field has grown rapidly, and here it has many applications. It is being widely used today to treat field boxes that are used by canneries and distributed to the farmer to use in picking fruits and vegetables. These boxes set on the wet ground in the fields, and are many times caught in the rain, causing them to swell and shrink excessively. The conditions are ideal for fungus growth (see Fig. 9). Many canneries buy their fruit and vegetables by the pound and if the boxes are soaked with water, they buy many pounds of water and pay the price of the fruit or vegetable. This one item alone is a big saving.

Shipping cases containing merchandise that can easily be damaged by water are treated with a water-repellent preservative. During the war many cases shipped overseas were treated to protect their contents (see Fig. 9).

Many bottlers today have found that if they treat their wood cases, they will last a great deal longer and be a better advertisement for them, in that the painting and lettering will stand up much longer, and the screws and nails used in holding the boxes together will not rust and let go as they do in untreated cases.

While no commercially practical way has been found to render wood completely waterproof, the practical benefits of good water-repellent preservation are attracting wide-spread attention throughout the lumber and wood products industries. Some species which, because of their characteristics, have been limited in their uses, are serving broader markets by such preservation. In some markets where the competition of wood and other materials is very keen, the position of wood is being strengthened by this type of protection. Being relatively economical, both in material cost and application, it does not "price" wood out of its natural markets. I am sure that as the knowledge of the effectiveness of good water-repellent preservatives becomes more generally known, the use of this type of treatment will continue to grow rapidly.

Discussion

Mr. E. W. Wellwood (Canadian Forest Products): When siding is dipped in a water-repellent, how does this affect the blistering of paint on the exterior or homes when a moisture barrier is not used on the warm side of the wall?

Mr. Garlick: It has proved very effective in guarding against blistering even though a moisture barrier is not used on the warm side of the wall although we always recommend a barrier on the warm side. We feel the best form of construction should always be used.

Mr. A. L. Mottet (Long–Bell Lumber Co.): Has the millwork preservative industry developed any long-term service records on the value of this class of preservatives?

Mr. Garlick: We know of no complete records from the mills, but many who have been treating for years tell us they have greatly reduced their complaints.

Mr. W. B. McSorley, Jr. (Columbia Door Co.): I have produced treated millwork for years and have found that complaints have been practically eliminated.

Dr. F. H. Kaufert (University of Minnesota): What is the effect of treatment with water-repellent preservatives on adhesion of putty in case of window sash?

Mr. Garlick: Service records indicate that treatment with water-repellent preservatives improves putty adhesion and reduces putty failure possibly because treatment prevents penetration of water and breaking of bond between wood

and putty. Water-repellent treatment also reduces penetration of oils from putty into wood —such oil penetration into untreated wood seems to result in putty failure, as it leaves the putty too dry.

Mr. R. E. Eby (West Coast Lumbermen's Assoc.): Is a three-minute dip considered only a temporary treatment?

Mr. Garlick: No, three minutes is standard throughout the millwork industry and siding, flooring and many other such items are given this length of dip; but items in contact with the ground or water should be given much heavier treatment.

Dr. H. D.. Erickson (University of Washington): Does the moisture content of exposed blocks correlate with the moisture content of windows?

Mr. Garlick: Yes, they check quite closely.

Mr. N. S. Perkins (Douglas Fir Plywood Assn.): Have you had any complaints on end products with such toxic treatments?

Mr. Garlick: No, except where the stock is not dry when used, there might be a complaint of odor but it would be mainly the spirits carrier, which soon leaves when stock is arranged so it can dry.

Mr. David Countryman (Douglas Fir Plywood Assn.): What is the experience with relation to dermatitis or other personal hazards involved in the use of toxic water-repellents? What percent of people are subject to complaints from this source?

Mr. Garlick: If reasonable care is taken and proper gloves and aprons are used, there should be no trouble except those people who are allergic to petroleum spirits or phenols. Blonds are more apt to be bothered than brunettes or colored people.

Mr. E. D. Marshall (Texas Forest Service, A & M College): In the standard three-minute dip, is there any specification with respect to temperature of the preservative and temperature of the wood?

Mr. Garlick: No. If both are 40 degrees F. or above, the results are satisfactory.

Mr. Marshall: It is my understanding that your product contains 3 percent resin content for water-repellency. Is this correct?

Mr. Garlick: No, it isn't, and resin content alone would not mean much as it takes a combination of several materials to make a good product.

Dr. Kaufert: What was the new oil-soluble preservative you mentioned? Was it copper 3-phenylsalicylate? Who makes it and who is working on it?

Mr. Garlick: Yes, it was copper 3-phenylsalicylate. It is made by The Dow Chemical Company, Midland, Michigan. Dow and our laboratory have been carrying out both laboratory and field tests. Results have been good to date.

Decay Resistance of Plywood Bonded with Various Glues

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The decay resistance of sweetgum and yellow birch plywood bonded with various glues is evaluated by the time it took wood-destroying fungi to penetrate the plywood, and by the loss in weight of the plywood when exposed to fungi in soil-burial tests. Several cold- and hot-pressed resin adhesives, as well as casein glue, with and without preservatives, were tested. None gave complete protection to the plywood.

Introduction

TESTS on the durability of plywood bonded with various glues under different conditions of exposure usually emphasize the effects of exposures and aging on the joint strength of the plywood, with only incidental consideration of the decay resistance of the wood or of the deterioration of the glue lines caused by micro-organisms. This is especially true in regard to the synthetic resin glues.

It is sometimes claimed that the synthetic resin glue imparts resistance to the plywood against fungus attack. While these claims indicate that some synthetic resin glues may be resistant to fungus deterioration, no actual data are available as to their effectiveness in protecting the surrounding wood.

This report gives the results of tests on three-ply, 3/32-inch plywood bonded with glues of various types. The decay resistance of the plywood was evaluated by the length of time it took the fungi to penetrate the plywood and by the loss in weight of the plywood specimens when buried in soil.

Penetration Tests

Test Materials

Since yellow birch and sweetgum are commonly used in the manufacture of hardwood plywood, these two woods were selected for this investigation. All material of both species consisted of 1/32-inch rotary cut sapwood veneer that was straight-grained and free of obvious defects. The veneer was bonded into three-ply panels with the following adhesives:

1. Casein
2. Casein plus 5 percent of sodium tetrachlorophenate by weight
3. Casein plus 5 percent of sodium trichlorophenate by weight
4. Casein plus preservative (Commercial Glue)
5. Hot-pressed resorcinol resin
6. Cold-pressed resorcinol resin
7. Cold-pressed resorcinol resin
8. Cold-pressed urea-formaldehyde resin
9. Cold-pressed urea-formaldehyde resin
10. Hot-pressed phenolic-resin film glue; double film used
11. Hot-pressed phenolic resin
12. Hot-pressed phenolic resin—(low pH)
13. Hot-pressed melamine resin

All of the resin glues were from different manufacturers.

Control specimens were made with film glue that had a hole 0.9 inch in diameter, cut from the glue films before assembling and pressing. Such a procedure gave a three-ply specimen similar to the others, but with the elimination of glue lines at the center of the specimen.

Polyporus versicolor, a white rotter, and *Lenzites trabea,* a brown rotter, were the fungi used in the penetration study. Both of these fungi are common wood destroyers and give good decay results in tests.

Methods of Test

The plywood, after being conditioned for about 2 weeks at 65 percent relative humidity and 80° F., was cut into disks about 3 inches

[1] In cooperation with the Forest Products Laboratory, maintained by the Forest Service, United States Department of Agriculture, at Madison, Wis., in cooperation with the Unviersity of Wisconsin.

in diameter. This size of specimen fitted nicely in the 90-millimeter Petri dishes used for the tests. The plywood disks were treated by four different methods designed in part to indicate the nature of any resistance to penetration offered by the glues. In one experiment the samples were tested with no prior treatment other than the preliminary conditioning. In a second experiment the specimens were flexed severely five times with and five times across the grain in an attempt to set up stresses that might produce checks in the glue lines. The specimens had a moisture content of about 10 to 12 percent, which made it possible to flex them to a radius of about 1.75 inches across the grain and of about 3.5 inches with the grain of the face plies. A third set of samples was soaked 24 hours in distilled water, dried 6 days at 30 percent relative humidity and 80° F., and again soaked and dried under the same conditions. After soaking, the moisture content of the specimens bonded with resin and casein adhesives was about 66 and 80 percent respectively. All had a moisture content of about 7 percent after drying.

In a fourth experiment a small hole about 1/32 inch in diameter was punched through the two glue lines and through the two upper plies of veneer so as to eliminate any mechanical barrier that the glue lines might have to fungus penetration. This hole was located at the center of the specimen where penetration would occur. Thus, any retardation of fungus penetration through such samples would be the result of the toxic properties of the adhesive, rather than that of a possible mechanical barrier of the glue lines.

Two specimens of each type of plywood and test group were tested against each of the two fungi.

In order to prevent the fungi from growing around and over the edges of the specimens, the edges were treated with a 5 percent solution of sodium pentachlorophenate. Preliminary tests showed that such edge treatment did not inhibit fungus growth or penetration

TABLE 1.—GROWTH OF LENZITES TRABEA AND POLYPORUS VERSICOLOR ON PLYWOOD SPECIMENS AFTER 2, 4, AND 7 WEEKS

Number and type of glue	Growth[1]					
	2 weeks		4 weeks		7 weeks	
	Lenzites trabea	Polyporus versicolor	Lenzites trabea	Polyporus versicolor	Lenzites trabea	Polyporus versicolor
Yellow Birch Sapwood						
1. Casein	+[2]	+	+	+	+	+
2. Casein plus 5 percent sodium tetrachlorophenate	V	G	V	F	V	V
3. Casein plus 5 percent sodium trichlorophenate	V	G	V	G	V	G
4. Casein plus preservative (commercial)	V	V	+	+	+	+
5. Hot-pressed resorcinol resin	V	V	V	V	V	V
6. Cold-pressed resorcinol resin	V	V	+	+	+	+
7. Cold-pressed resorcinol resin	V	V	+	+	+	+
8. Cold-pressed urea-formaldehyde resin	G	V	V	V	+	+
9. Cold-pressed urea-formaldehyde resin	F	P	P[3]	VP[3]	V	VP
10. Hot-pressed phenolic resin (film)	V	V	V	V	+	+
11. Hot-pressed phenolic resin	V	G	G	F	V	G
12. Hot-pressed phenolic resin (low pH)	F	P	P	P	P	VP
13. Hot-pressed melamine resin	V	V	V	V	V	V
Sweetgum Sapwood						
1. Casein	+	+	+	+	+	+
2. Casein plus 5 percent sodium tetrachlorophenate	V	V	V	V	V	V
3. Casein plus 5 percent sodium trichlorophenate	V	V	V	V	V	V
4. Casein plus preservative (commercial)	V	V	V	V	+	+
5. Hot-pressed resorcinol resin	V	G	V	V	V	V
6. Cold-pressed resorcinol resin	V	V	+	+	+	+
7. Cold-pressed resorcinol resin	V	V	+	+	+	+
8. Cold-pressed urea-formaldehyde resin	P	V	VP[3]	V	+	+
9. Cold-pressed urea-formaldehyde resin	F	F	P[3]	VP[3]	F	G
10. Hot-pressed phenolic resin (film)	V	V	V	V	V	V
11. Hot-pressed phenolic resin	V	G	G	G	G	V
12. Hot-pressed phenolic resin (low pH)	P	P	VP[3]	F	VP	P
13. Hot-pressed melamine resin	G	G	F	G	F	G

[1] V = Vigorus growth
G = Good growth
F = Fair growth
P = Poor growth
VP = Very poor growth

[2] + means fungus penetrated specimen previous to examination.

[3] Plywood specimens transferred to fresh feeder blocks after 5 weeks.

through the central portion of the sample. After being sterilized for 20 minutes at 10 pounds pressure, the specimens were placed in Petri dishes on 1- by 1- by ¼-inch fiberboard feeder blocks that had been impregnated with a 2 percent solution of malt extract and inoculated with the test fungus. The specimens were then incubated at about 80° F. Sterile distilled water was added to the Petri dishes at weekly intervals, or when needed, in order to maintain sufficient moisture for fungus growth.

Daily examinations were made for penetration and the general condition of the test fungus. Penetration was determined visually. Where the fungus growth was poor after 5 weeks, the plywood specimens were transferred to fresh feeder blocks.

The tests were repeated on replicate material after 1 year in order to ascertain the effect of aging on the glue lines. The replicate material was kept at room temperature during that time. The flexed specimens were not included in this later test.

Results

Lenzites trabea and *Polyporus versicolor* exhibited poor to vigorous growth on the plywood specimens depending upon the type of glue bond. The growth of the two fungi after 2, 4, and 7 weeks is shown in Table 1. Casein adhesive, either untreated or treated, did not slow up fungus growth on the feeder block nor on the test specimens. Cold-pressed resorcinol resin and film glue also had no initial inhibiting effects on the fungi, whereas a cold-pressed urea-formaldehyde and hot-pressed phenolic resin with a low pH value inhibited fungus growth.

The number of days *Lenzites trabea* and *Polyporus versicolor* took to penetrate through the yellow birch and sweetgum plywood specimens bonded with various glues is shown in Table 2. As might be expected, the plywood bonded with untreated casein glue was only slightly more resistant to penetration than the controls, which had no glue lines above the inoculum at the place of penetration. On the other hand, the casein glue treated with either 5 percent sodium tetrachlorophenate or 5 percent sodium trichlorophenate was quite resistant to penetration. In fact, some of the specimens were not penetrated after an elapsed time of 150 days, at which time the test was discontinued. The preservatives were more toxic to *Lenzites trabea* than to *Polyporus versicolor*. All of the treated casein-bonded specimens were delaminated after 80 days.

A commercially treated casein glue, the kind and amount of preservative of which was unknown, was only slightly more resistant than the untreated casein glue.

Of the resin glues, cold-pressed resorcinol resin and the phenolic resin film offered the least resistance to the fungi. These glues apparently had no toxic effect, since the fungi penetrated them readily when a small hole was punched through the glue lines. As a consequence, it is reasonable to assume that these glues retarded penetration through the specimens by serving as a mechanical barrier.

It should be emphasized that a double glue film was used at each glue line in this test. A single film at each of the two glue lines was penetrated in 17 days by *Lenzites trabea* in a preliminary test. On microscopic examination of a cross section from this specimen the mycelium of the fungus was observed to follow along the glue film, and to penetrate only at small openings.

Hot-pressed resorcinol resin was more resistant to penetration than were the cold-pressed resins of this type. It was not determined whether this resistance was the result of the heat used in pressing, which may possibly cause certain components of the resin to penetrate deeper into the wood cells, or whether the hot-pressed glue was inherently more toxic.

Plywood made with one of the two cold-pressed urea-formaldehyde resins was penetrated in slightly less than half the time required for penetrating the other. Differences in the toxic qualities of the glues rather than in barrier effect seemed to be concerned.

The phenolic resin glues, other than the film glue, showed much the same trend as the urea glues, in that one was moderately resistant and the other very resistant to penetration.

Hot-pressed melamine resin was quite toxic, since the hole did not decrease the time of penetration.

The sapwood of sweetgum was penetrated more readily, as a general rule, than that of yellow birch.

TABLE 2.—NUMBER OF DAYS REQUIRED FOR LENZITES TRABEA AND POLYPORUS VERSICOLOR TO GROW THROUGH THREE-PLY 5/32-INCH YELLOW BIRCH AND SWEETGUM PLYWOOD WHEN TESTED SOON AFTER GLUING

Number and type of glue	Treatment of plywood: Untreated[1] L. trabea	Untreated[1] P. versicolor	Flexed[2] L. trabea	Flexed[2] P. versicolor	Cyclic wet and dry[3] L. trabea	Cyclic wet and dry[3] P. versicolor	1/32-inch hole[4] L. trabea	1/32-inch hole[4] P. versicolor
Yellow Birch Sapwood								
1. Casein	14	8½	12	9	16	8	7½	4
2. Casein plus 5 percent sodium tetrachlorophenate	X[5]	78	X	113[6]	X	52	X	20
3. Casein plus 5 percent sodium trichlorophenate	X	X	X	117[6]	X	46[6]	X	40
4. Casein plus preservative (commercial)	24	25	----	----	20	27	19	39
5. Hot-pressed resorcinol resin	144	31	107	75	52	50	96	4[6]
6. Cold-pressed resorcinol resin	28	31	25	32	22	17	8	6½
7. Cold-pressed resorcinol resin	29	22	27	21	19	20	12	7½
8. Cold-pressed urea-formaldehyde resin	93[6]	51	45	41	34	17	35	38
9. Cold-pressed urea-formaldehyde resin	[7]	111	106[6]	113	41	57	X	107
10. Hot-pressed phenolic resin—film[8]	56	62[6]	54	57	51	43	9	4
11. Hot-pressed phenolic resin	91	101	77	120[6]	39	58[6]	46	15[6]
12. Hot-pressed phenolic resin	X	X	X	X	53[6]	X	133[6]	X
13. Hot-pressed melamine resin	X	72	[7]	75	81	67[6]	133[6]	107
14. Control—no glue bond[9]	6½	6	7	5	5½	6	3½	3
Sweetgum Sapwood								
1. Casein	6	5½	8½	7	12	6½	3½	4
2. Casein plus 5 percent sodium tetrachlorophenate	X	51	X	47	49[6]	19	X	13
3. Casein plus 5 percent sodium trichlorophenate	X	48[6]	X	52[6]	X	26	X	25
4. Casein plus preservative (commercial)	20	35	----	----	----	30	20	18
5. Hot-pressed resorcinol resin	84	66	81	58	52[6]	45	92	48
6. Cold-pressed resorcinol resin	22	12	19	20	17	14	12	8
7. Cold-pressed resorcinol resin	19	17	16	26	17	10	8	8
8. Cold-pressed urea-formaldehyde resin	75	61	56	41	18	16	47	16
9. Cold-pressed urea-formaldehyde resin	142[6]	69	96	71	71	25	106[6]	93[6]
10. Hot-pressed phenolic resin—film[8]	80	129[6]	63	67	25	15	4	4
11. Hot-pressed phenolic resin	63	55	97	52[6]	75	48	52	32[6]
12. Hot-pressed phenolic resin	X	105[6]	X	X	65	64[6]	X	X
13. Hot-pressed melamine resin	135	76	113[6]	90	X	39[6]	X	73[6]
14. Control—no glue bond[9]	5½	5	[6]	5	7	5	4	2½

[1] All specimens conditioned at least 2 weeks at 65 percent relative humidity and 80° F. Untreated samples given no further treatment.
[2] Specimens flexed severely 5 times with and 5 times across the grain.
[3] Specimens soaked 24 hours in distilled water, dried 6 days at 30 percent relative humidity and 80° F. and then repeated.
[4] 1/32-inch hole made through glue lines and 2 veneer layers.
[5] X means no penetration occurred during 150 days of test.
[6] Only 1 of the 2 replicate specimens was penetrated.
[7] Fungus grew around edge of specimen before penetration.
[8] Double film used at each glue line.
[9] Controls bonded with film glue with a hole 0.9 inches in diameter cut from glue films at place of penetration.

Flexing, with the exception of the least toxic of the urea resin specimens (number 8 in table 1), had little or no effect in hastening penetration.

All of the glues, other than untreated casein, were penetrated more readily after the cyclic wet and dry treatment. This treatment probably set up stresses in the wood and glue lines, and also leached out some of the toxic constituents in the glue. Of these, formaldehyde may have been leached out from some of the resin glues, and chlorophenols from the treated casein glues.

It may be noted in Table 2 that *Polyporus versicolor* penetrated most specimens in a shorter time than *Lenzites trabea*. The chlorophenols, especially, were very toxic to *L. trabea*.

The results of the effect of aging on the durability of the various adhesives are shown in Table 3. Although some differences in time of penetration can be noted between the earlier and the subsequent test, the general trend of resistance is much the same. However, aging apparently reduced the penetration resistance of the untreated cold-pressed urea glues nearly as much as the soaking and drying treatment. This was presumably the result of formaldehyde evaporating from the specimens or crazing of the glue film during the year.

Soil Burial Tests

Methods of Test

Plywood specimens were subjected to soil burial in order to ascertain the durability of the plywood as measured by losses in weight as well as by the rate of fungus penetration. The specimens were similar to those used in the penetration studies, except that the cold-pressed resorcinol resins and commercially treated casein adhesives were omitted. These were not available at the time the soil testing was done.

The specimens were approximately 1¼ by 3 inches. They were conditioned, before and after burial in the unsterilized soil, to an equilibrium moisture content of about 6 percent in a room maintained at 30 percent relative humidity and 80° F. The weights of the specimens were recorded at each conditioning period, and the loss in weight was calculated from these weights.

Two loosely covered aquaria, each 2½ cubic feet in capacity, were used for the test. Ordinary top soil—a dark sandy loam—was thoroughly mixed, and enough water added to bring the moisture content of the soil to about 40 percent by weight on an oven-dry basis. Each aquarium was filled approximately two-thirds full. In one aquarium a pint of corn inoculated with *Poria incrassata* was added to the soil. This was thoroughly mixed with the soil. Molds grew freely on the corn in the soil, and apparently they reduced the vigor of *P. incrassata*.

Three specimens representing each glue were set ½ inch below the top of the soil in each aquarium. They were incubated 2½ months in the corn-enriched soil, and for three months in the plain soil. The soil was kept moist during the incubation period by adding distilled water as needed.

Results

The results, shown in Table 4, demonstrate that the resin adhesives have some effect on preserving the wood, but do not wholly protect it. Casein glue treated with either 5 percent sodium tetrachlorophenate or 5 percent

TABLE 3.—NUMBER OF DAYS REQUIRED FOR LENZITES TRABEA AND POLYPORUS VERSICOLOR TO GROW THROUGH THREE-PLY, 3/32-INCH YELLOW BIRCH AND SWEETGUM PLYWOOD AFTER AGING 1 YEAR

Number and type of glue	Treatment of plywood: Untreated[1] L. trabea	Untreated[1] P. versicolor	Cyclic wet and dry[2] L. trabea	Cyclic wet and dry[2] P. versicolor	1/32-inch hole[3] L. trabea	1/32-inch hole[3] P. versicolor
Yellow Birch Sapwood						
1. Casein	19	18	15	11	16	----
2. Casein plus 5 percent sodium tetrachlorophenate	X[4]	94	X	114	X	101[5]
3. Casein plus 5 percent sodium trichlorophenate	X	117[5]	X	110[5]	X	87[5]
4. Casein plus preservative (commercial)	----	----	----	----	----	----
5. Hot-pressed resorcinol resin	118	103[5]	51[5]	113	81	90
6. Cold-pressed resorcinol resin	21	25	18	20	14	25
7. Cold-pressed resorcinol resin	30	28	20	16	10	7
8. Cold-pressed urea-formaldehyde resin	26	19	24	23	36	20
9. Cold-pressed urea-formaldehyde resin	77	84	40	42	102	50
10. Hot-pressed phenolic resin—film[6]	36	46	32	52	19	65
11. Hot-pressed phenolic resin	84	105	55[5]	123[5]	42	93[5]
12. Hot-pressed phenolic resin	X	105[5]	48[5]	X	X	X
13. Hot-pressed melamine resin	89[5]	78	82[5]	58[5]	X	54
14. Control—no glue bond[7]	9	10	8	10	16	12
Sweetgum Sapwood						
1. Casein	20	18	10	12	7	12
2. Casein plus 5 percent sodium tetrachlorophenate	X	81	X	90	136	133
3. Casein plus 5 percent sodium trichlorophenate	101	129	X	54	X	55[5]
4. Casein plus preservative (commercial)	----	----	----	----	----	----
5. Hot-pressed resorcinol resin	50	50	25[5]	19	48	53
6. Cold-pressed resorcinol resin	24	40	15	19	12	34
7. Cold-pressed resorcinol resin	33	28	15	12	12	8
8. Cold-pressed urea-formaldehyde resin	39	19	18	17	59	24
9. Cold-pressed urea-formaldehyde resin	81	31	56	53	97	50
10. Hot-pressed phenolic resin—film[6]	30	58	32	X	33	29
11. Hot-pressed phenolic resin	69	77	39	112[5]	43	89[5]
12. Hot-pressed phenolic resin	98[5]	83	25	X	133[5]	151[5]
13. Hot-pressed melamine resin	61[5]	74	86	41	102	68
14. Control—no glue bond[7]	16	14	8	11	5½	17

[1] All specimens aged 1 year. Untreated ones given no further treatment.
[2] Specimens soaked 24 hours in distilled water, dried 6 days at 30 percent relative humidity and 80° F. and then repeated.
[3] 1/32-inch hole made through glue lines and 2 veneer layers.
[4] X means no penetration occurred during the 155 days of test.
[5] Only 1 of 2 replicate specimens was penetrated.
[6] Double film used at each glue line.
[7] Control bonded with film glue with a 0.7 square inch area cut from film at place of penetration.

TABLE 4.—WEIGHT LOSS OF YELLOW BIRCH AND SWEETGUM PLYWOOD AFTER EXPOSURE IN SOIL FOR 2½ AND 3 MONTHS

Number and type of glue	Weight loss[1]			
	Yellow birch		Sweetgum	
	2½ months exposure Percent	3 months exposure Percent	2½ months exposure Percent	3 months exposure Percent
1. Casein	40	--[2]	39	53
2. Casein plus 5 percent sodium tetrachlorophenate	33	50	36	46
3. Casein plus 5 percent sodium trichlorophenate	25	54	27	29
5. Hot-pressed resorcinol resin	19	26	12	25
8. Cold-pressed urea-formaldehyde resin	25	38	15	34
9. Cold-pressed urea-formaldehyde resin	29	37	16	34
10. Hot-pressed phenolic resin—film[3]	30	35	15	31
11. Hot-pressed phenolic resin	19	35	12	27
12. Hot-pressed phenolic resin	10	18	10	16
13. Hot-pressed melamine resin	28	38	12	34

[1]Each figure is the average of 3 specimens.
[2]Specimens so badly deteriorated that they were impossible to remove.
[3]Double film used at each glue line.

sodium trichlorophenate failed to give good protection under such a severe test. Of the resin glues, the low pH (2.0) phenolic resin glue gave the best protection to the plywood. This adhesive also offered the most resistance to penetration. The hot-pressed resorcinol resin gave fair protection to the plywood, while the other resin adhesives were about equally inferior. None of the glues gave adequate protection to the wood.

It should be emphasized that the veneer in this test was only 1/32 inch thick. It is reasonable to suppose that any protection given to the wood by the adhesive would decrease as the thickness of the veneer or other form of wood increased.

Summary

Comparisons of the penetration of *Polyporus versicolor* and *Lenzites trabea* growing on fiberboard feeder blocks showed that the resin and treated and untreated casein adhesives did not completely protect three-ply, 3/32-inch plywood of yellow birch and sweetgum sapwood. Soil burial tests verified these results.

Untreated casein adhesive showed little resistance to fungi in both the penetration and soil burial tests. Casein treated with either 5 percent sodium tetrachlorophenate or 5 percent sodium trichlorophenate was fairly resistant to penetration, although these treated specimens delaminated after about 80 days in the penetration tests.

A commercial casein adhesive containing a preservative gave only slightly more protection against penetration than untreated casein.

A liquid phenolic resin with a pH of 2.0 gave the best protection of any of the adhesives. A second resin of this type was intermediate in effect.

A phenolic resin film glue proved non-toxic to the fungi, but a double film at each glue line acted as a mechanical barrier.

Hot-pressed resorcinol resin was much more resistant to penetration than cold-pressed resins of this type. The cold-pressed resorcinol resins seemed non-toxic to the test fungi.

Two cold-pressed urea-formaldehyde resins differed widely in penetration time, but reacted similarly in soil burial tests.

Hot-pressed melamine resin retarded penetration appreciably, but gave little protection to plywood buried in the soil.

No significant difference in penetration time was noted between samples that were flexed as compared to those not flexed before testing. Cyclic soaking and drying before testing decreased penetration time about 20 percent for all adhesives.

FOREST PRODUCTS RESEARCH SOCIETY

Occurrence of Gelatinous Fibers and Their Effect Upon Properties of Hardwood Species

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Wood fibers with gelatinous-appearing inner layers have received considerable attention during the past 15 years in Australia, England, and the United States because of their harmful effects upon some properties of commercially valuable hardwood species.

The results of recent investigations on gelatinous fibers and their effects are summarized in this paper for the purpose of coordinating and evaluating the information obtained in research at the Forest Products Laboratory and elsewhere. It is hoped that the summary will promote further investigations of this type of hardwood structure, for only by such investigations can its industrial significance be evaluated and practical means of identifying it in logs and lumber be developed.

Previous Observations on Gelatinous Fibers Structure and Gross Appearance

GELATINOUS fibers are identified under the microscope by the shiny and gelatinous appearance of the inner portion of the secondary cell wall, which looks so much like a distinct layer of the fiber wall that it has been referred to by some authors as "the tertiary wall" (*3*)[2]. In woods normally having thin-walled fibers, such as cottonwood and willow, the gelatinous layer is thin and a portion of it is often found buckled into the fiber lumen in a microscopic section. When freshly cut green material is sectioned and examined microscopically, less buckling of the gelatinous layers is found than in material that has been oven-dried. In species with thick-walled fibers, such as oak, the gelatinous layer is usually thick and so swollen that the fiber lumen is small and irregular in shape compared to that of normal fibers.

Clarke (*5*) found that gelatinous-fiber zones in end sections of beech were silvery and more lustrous than the rest of the end surface. An examination of freshly cut southern willow at the Forest Products Laboratory showed an abundance of gelatinous fibers in annual rings that had a peculiarly silky and lustrous appearance.

Effects of Reagents and Dyes

The gelatinous layers react to chloriodide of zinc by swelling considerably into the fiber cavity and staining blue or purple. With phloroglucin, the middle lamella, primary wall, and outer portion of the secondary wall are stained pink, while the inner portion of the secondary wall (the gelatinous portion) is unstained and frequently lies shriveled in the lumen of the fiber.

Various biological dyes can be used in making permanent preparations for the microscopic identification of gelatinous fibers. The gelatinous layer stains green with aqueous safranin and alcoholic fast green, blue with safranin and picro-anilin blue, and red with crystal violet and erythrosin, whereas the outer portion of the wall of gelatinous fibers and the entire wall of normal fibers stain red, yellow, and purple, respectively, with these stains (*1*). The gelatinous layer stains most readily with the so-called "cellulose stains," while the rest of the fiber wall stains with so-called "lignin stains." Although these differentially staining reagents and dyes are useful in identifying gelatinous fibers, they cannot be used to determine the extent of lignification nor the development of cellulose in the secondary walls.

[1] Maintained at Madison 5, Wis., in cooperation with the University of Wisconsin.

[2] Numbers in parentheses refer to Literature Cited at end of paper.

The gelatinous layer has been claimed to be relatively rich in hemicelluloses according to Rendle (*11*). Recent chemical analyses of beech wood with gelatinous fibers in comparison to wood with normal fibers showed a significantly lower content of lignin and higher Cross and Bevan cellulose content in the gelatinous fibers than in normal-fibered wood. The pentosan content of holocellulose obtained by standard methods was found to be higher in normal fibers than in gelatinous ones, from which difference Chow (*2*) concluded that the gelatinous fibers have higher proportions of cellulose with relatively longer cellulose chains than the normal fibers.

Distribution and Relation to Tension Wood

Gelatinous fibers may occur singly, in isolated groups, or in broad bands. Potter (*10*) found that they were more frequent in the early growth rings of a tree, and that in later growth rings they tended to be concentrated on one side of the stem during any growth period. Their distribution may vary at different heights in a tree; they are sometimes well-developed in one ring and absent in the next. According to Clarke (*3*), they tend to be proportionately more abundant in broad than narrow rings. Well-developed gelatinous fibers also were found by him (*5*) on the upper, or tension, side of leaning English beech trees. In general, the beech cross sections were eccentric with the gelatinous fibers on the longest radii in the lower part of the trunk; higher in the tree, however, they occurred on all radii of disks but were not present in all parts of the same annual rings. Dadswell (*7*) found typical bands of tension wood in long straight trunks of New Guinea trees, in which this type of structure is not usually suspected.

Early observations that gelatinous fibers tend to occur on the upper, or tension, side of leaning tree trunks, have led to the association of gelatinous fibers with "tension wood" in hardwoods (*5*, *11*). The use of the term "tension wood" implies that this type of structure is formed in response to the tensile stresses peculiar to the upper side of inclined parts of trees. Early investigators felt that tension wood might be influential in the straightening of leaning trees, assuming that the tension wood pulled the tree back to the erect position. Both tensile stresses and gravity have been suggested as producing the physiological conditions necessary for the formation of gelatinous fibers by the cambial initials at particular points in the circumference of branches and inclined trunks of trees (*5*).

Effects on Properties of Wood

Rendle (*11*) reported that the presence of gelatinous fibers causes defects or abnormalities in machining and seasoning of hardwood species in addition to affecting adversely some strength properties of the wood.

Abnormal Surfaces.—Sawed, machine-planed, turned, and shaped pieces of wood and also sheets of veneer sometimes have fuzzy or fibrous-appearing surfaces. Planed surfaces of English beech (*5*) that contained gelatinous fibers were observed to be more woolly than normal in parts that were cut against the grain. At the U. S. Forest Products Laboratory fuzzy streaks and irregular areas were observed on the surfaces of sliced mahogany veneer in which the protruding fibers were pulled from the adjacent sheets. Such fibers on the end grain of logs and lumber are frequently bent in one direction by the pressure of the circular saw blade. Dadswell (*7*) reported that production of lumber from some New Guinea species was seriously impaired by the frequent clogging of saw teeth with masses of loose fibrous material. Veneer cut from one side of a large eccentric southern cottonwood log had fuzzy surfaces, while that from the opposite side was relatively smooth (*1*). Such fuzzy areas were ascribed to gelatinous fibers that had been torn free on one end instead of being cut cleanly.

Strength Properties.—Gelatinous fibers were found by Clarke (*3*) to be relatively common in specimens of elm weak in maximum crushing strength along the grain, although such specimens were not necessarily low in density. Some exploratory determinations on mahogany and khaya also indicated that gelatinous fibers were more common in end-crushing specimens with relatively low strength values than in ones with higher strength but with approximately the same density. The end-crushing strength of tension wood in beech also was found by Clarke (*5*) to be much lower than in normal wood, irrespective of density, and to result in gradual buckling failures in contrast to the

localized compression failures that are frequently associated with relatively high crushing strength along the grain. In a few tests, the tensile strength was higher for tension wood than for normal wood specimens, and the toughness was not found to be appreciably lower when gelatinous fibers were present than when they were absent. Koehler (*8*) reported that gelatinous fibers occurred sporadically in both tough and brash specimens of commercial white oak. Some of the work on Australian woods indicated relationships between the distributions of tension wood and of brittle heart as identified by broken fibers that, in turn, were found to cause relatively low impact-bending strength (*6*).

Longitudinal Shrinkage and Collapse.—Excessive longitudinal shrinkage of hardwood species frequently is related to the presence of gelatinous fibers. Clarke (*4*) reported that a shoe-last block split approximately along the junction between the smooth, normal wood and the woolly portions as a result of higher longitudinal shrinkage in the woolly part. The investigations on the longitudinal shrinkage of tension wood and of normal wood in English beech resulted in higher and somewhat more erratic values in the tension wood than in the normal wood (*5*). A few exploratory determinations on willow from the Mississippi River Delta area showed generally higher, but erratic, longitudinal shrinkage when small to large amounts of gelatinous fibers were present than when they were absent.

The rough veneer cut from one side of the large southern cottonwood log had irregular corrugations when dried whereas the veneer from the opposite side of the log cut uniformly and smoothly, and dried satisfactorily. Fig. 1 shows flat and corrugated veneer from opposite sides of the log. Baudendistel and Akins (*1*) investigated variations of longitudinal shrinkage of the wood in relation to the occurrence of gelatinous fibers in specimens from the long and short radii on opposite sides of this eccentric log. Specimens with low longitudinal shrinkage contained few or no gelatinous fibers, whereas those with high shrinkage contained many.

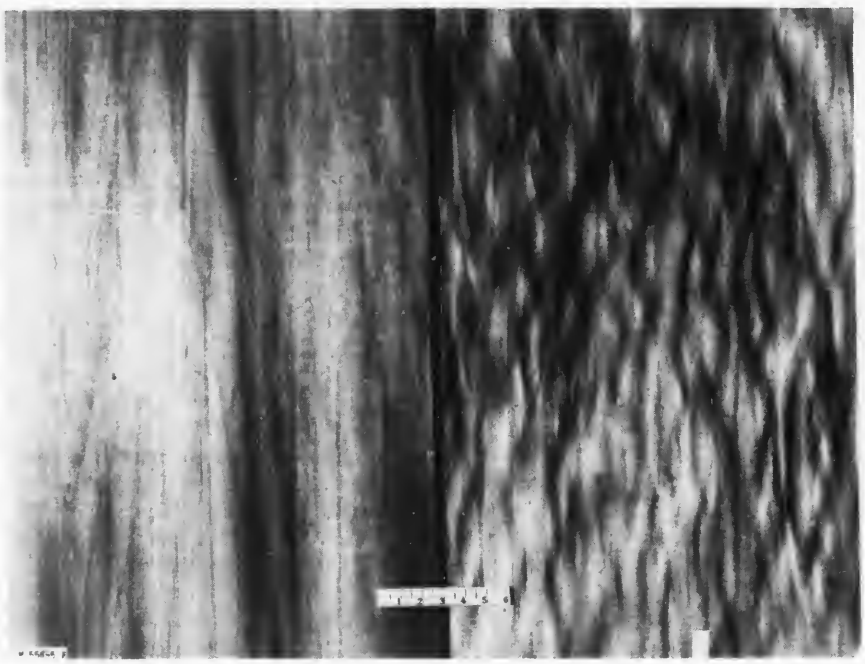

Fig. 1.—Southern cottonwood veneer from an eccentric log showing (left) a flat sheet from the side with the shorter radii; and (right) a buckled sheet from the side with the longer radii.

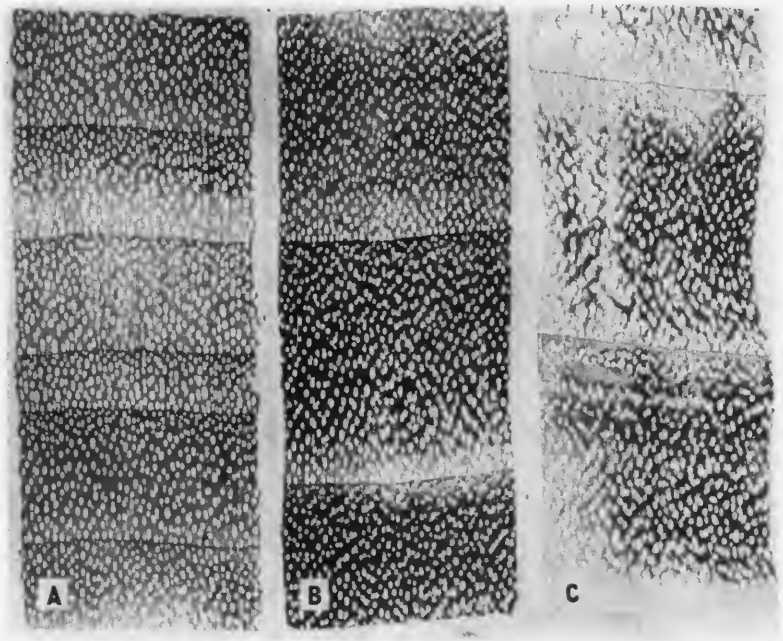

Fig. 2.—Photomicrograph of transverse sections of longitudinal-shrinkage specimens from an eccentric cottonwood log, A, Small number of gelatinous fibers in the small, scattered, and darkly stained areas; B, abundant gelatinous fibers in lower two rings and scattered distribution in upper ring; and C, abundant gelatinous fibers in partially collapse areas.

Specimens containing abundant gelatinous fibers frequently showed collapse in which the fiber walls were severely distorted. Similar collapse that did not respond to the usual reconditioning treatments has been noted in Australian species (6). Fig. 2 shows photomicrographs of cross sections from longitudinal-shrinkage specimens, one of which has a small amount and two of which have large amounts of gelatinous fibers, one of the latter showing considerable collapse.

Recent Observations

Serious defects have been observed in hardwood veneer cut at the Forest Products Laboratory. Defects were investigated that appeared to be the result of gelatinous fibers in certain parts of logs. In addition, pieces from relatively large cottonwood limbs and from one leaning white oak tree were obtained for investigating the occurrence of gelatinous fibers and variations in longitudinal shrinkage with respect to inclined limbs and trunks of trees.

Black Cottonwood Veneer

While western black cottonwood veneer was being cut, it was observed that one side of each of three bolts from different trees produced veneer with fuzzy surfaces and of irregular thickness. Even when freshly cut, the fuzzy veneer was slightly buckled, and during drying it split and buckled seriously. Fig. 3 shows cottonwood veneer with fuzzy surfaces and fissures.

Two of these bolts were eccentric, while the third was concentric. The defective veneer from the two eccentric bolts was cut from the side with the shortest radii with respect to the pith, while the veneer suitable for plywood faces was cut from the opposite side. The bolts were chucked in the lathe so that they revolved around their geometric centers. Thus, the sheet of veneer peeled in any one revolution of the two eccentric bolts included portions of relatively widely separated annual rings across its width, while that from one revolution of the concentric bolt included the same or very closely adjacent annual rings. Small specimens from

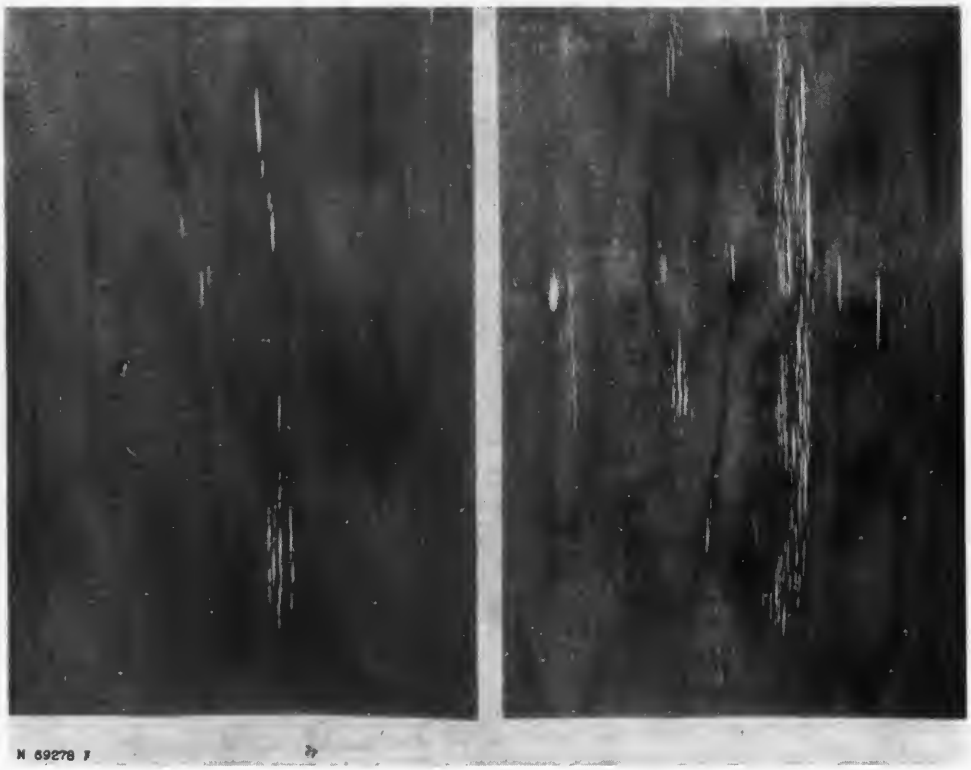

Fig. 3.—Black cottonwood veneer $\frac{1}{16}$ inch and $\frac{1}{32}$ inch thick (left and right, respectively) against an illuminated background showing fuzzy surfaces and fissures.

cross sections at the ends of the bolts were matched with the parts of the sheet of veneer containing satisfactory and defective portions in one revolution of the bolt. With respect to the two eccentric logs, additional specimens were obtained from the same annual rings on the opposite side of the bolt as those from which defective veneer was produced (Fig. 4). Transverse microtome sections from these specimens were examined for gelatinous fibers.

Gelatinous fibers were abundant on the side that produced the fuzzy, buckled, and split veneer in all three bolts. Practically no gelatinous fibers were found in the specimens from the other side of these bolts, except along one of the three radii in one bolt (No. 3), as shown in Fig. 4. In this bolt the gelatinous fibers appeared to extend considerably beyond the part from which defective veneer was cut, although they were less abundant in the part from which satisfactory veneer was cut than on the opposite side. Clarke (*5*) noted that gelatinous fibers diminished in abundance to either side of where such fibers occupied approximately the entire width of the rings.

Large Cottonwood Limbs

The occurrence of gelatinous fibers on upper and lower sides of large limbs and their relation to longitudinal shrinkage were investigated, since limbs normally deviate considerably from vertical positions. Two southern cottonwood limbs from freshly cut trees were used for this study. Crescent-shaped bands that had the lustrous appearance associated with tension wood, were present in some annual rings on the upper side of the cross section of one limb that grew horizontally. No tension wood was visually identified in the other limb, which had grown at an angle of about 40° to the hori-

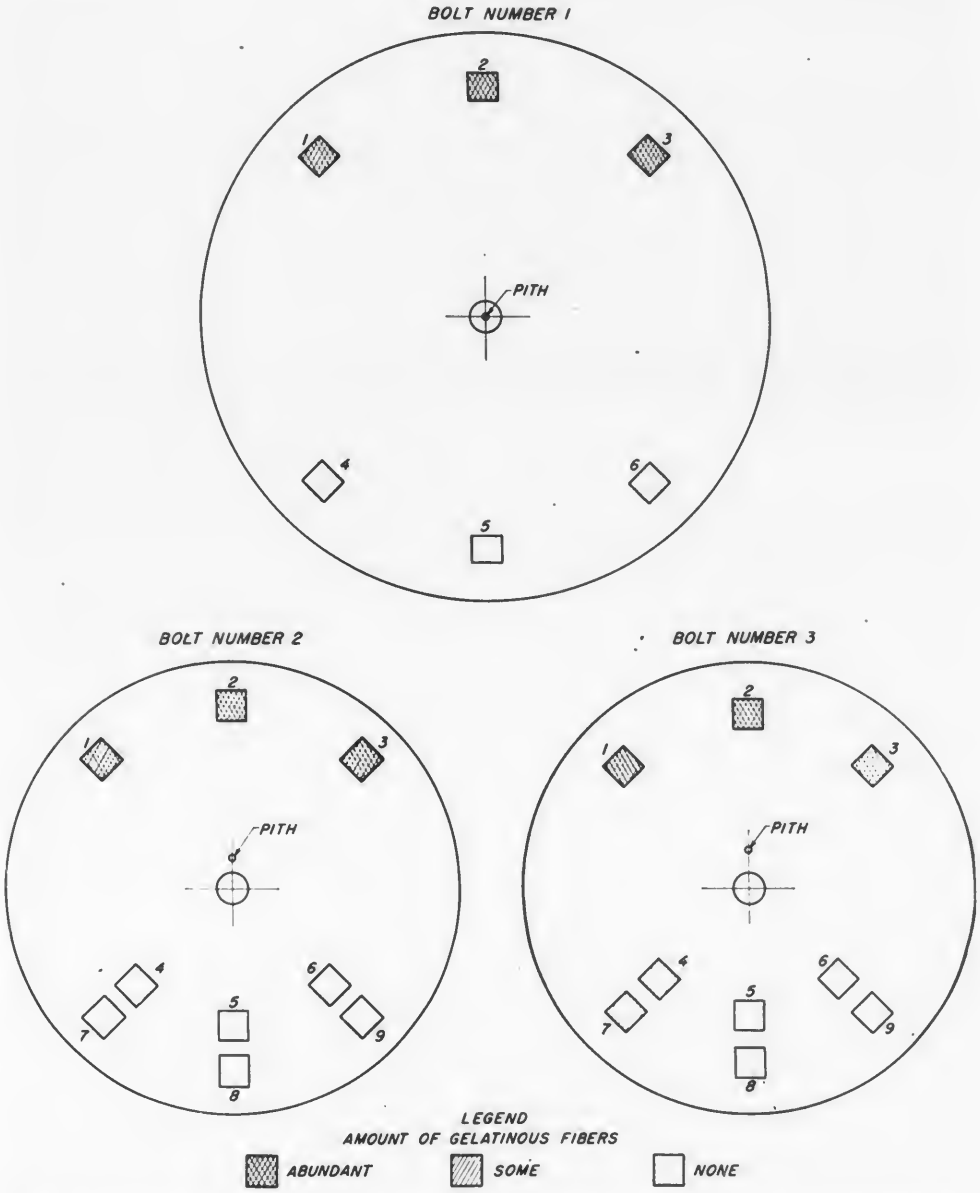

Fig. 4.—Diagrams of black cottonwood logs showing positions of the specimens for determinations of the distribution of gelatinous fibers.

zontal position and was approximately concentric. The longitudinal shrinkage was determined on the upper and lower sides of these limbs.

Transverse microtome sections from selected shrinkage specimens were examined for gelatinous fibers. An abundance of gelatinous fibers and high longitudinal shrinkage were found in wood from the upper or tension sides of the cottonwood limbs, while practically no gelatinous fibers and low longitudinal shrinkage occurred in wood from the lower sides (Table 1). This indicated some relationships between gelatinous fibers, longitudinal shrinkage, and the degree of inclination in cottonwood limbs.

TABLE 1.—LONGITUDINAL SHRINKAGE AND ESTIMATED AMOUNTS OF GELATINOUS FIBERS IN SPECIMENS FROM UPPER AND LOWER SIDES OF TWO COTTONWOOD LIMBS

Side of limb	Specimen	Longitudinal shrinkage Percent	Estimated amount of gelatinous fibers
Upper[1]	1-1-1	1.09	----
	1-1-2	1.17	Large
	1-1-3	.88	----
	1-1-4	1.05	Large
	1-1-5	1.15	----
	1-1-6	.94	----
	1-1-7	.85	Large
	1-1-8	.96	----
	1-1-9	.97	----
	1-1-10	.87	----
	Average	.99	----
Lower[1]	1-2-1	.32	None
	1-2-2	.22	----
	1-2-3	.21	----
	1-2-4	.22	----
	1-2-5	.15	None
	1-2-6	.14	----
	1-2-7	.18	----
	1-2-8	.16	Very few[2]
	1-2-9	.19	----
	Average	.20	----
Upper[3]	2-1-1	.54	Small
	2-1-2	.38	Small
	2-1-3	.59	Large
	2-1-4	.40	Moderate
	2-1-5	.46	Moderate
	2-1-6	.30	Small
	2-1-7	.26	Small
	Average	.42	----
Lower[3]	2-2-1	.26	None
	2-2-2	.20	None
	2-2-3	.19	None
	2-2-4	.13	None
	2-2-5	.15	None
	2-2-6	.15	None
	2-2-7	.19	None
	Average	.18	----

[1] Horizontal limb.
[2] In one annual ring.
[3] Inclined limb, 40° to the horizontal.

Leaning White Oak Tree

A leaning white oak tree was investigated in order to determine the relationship between gelatinous fibers and longitudinal shrinkage with respect to the upper, or tension, side of the trunk. This white oak tree, 20 inches in diameter at breast height, that had leaned 16° in the north-northeast direction. The cross sections of the trunk at about 2 and 10 feet above the ground were eccentric, with the longest radii on the upper side of the trunk and the shortest radii on the lower side, and thus coincided with the general direction of lean. At 18 feet the diameter through the longest and shortest radii was approximately in the northeast and southwest directions, in contrast to the respective diameters at 2 and 10 feet, where it was more nearly north-northeast and south-southwest. From this it is assumed that the direction of the lean at 18 feet was slightly different than at the lower levels. Table 2 shows the eccentricity at 2, 10, and 18 feet above the ground, based upon distances from the pith to the bark as the ratio of lower to upper diametrically opposite radii approximately parallel to the direction of lean.

TABLE 2.—ECCENTRICITY BASED ON THE RATIO OF UPPER TO LOWER DIAMETRICALLY OPPOSITE SIDES OF A LEANING WHITE OAK TREE

Height above ground	Eccentricity ratio	Direction of measured diameter
Feet	Upper/Lower	
2	1.31:1	N-NE to S-SW
10	1.44:1	N-NE to S-SW
18	1.41:1	NE to SW

Longitudinal shrinkage and specific gravity were determined along four radii, designated as 1 and 2 on the upper and as 3 and 4 on the lower side with respect to the general direction of the lean of the tree at levels of about 2, 10, and 18 feet above the ground.

The longitudinal shrinkage specimens from both the long radii of the *A* and *C* bolts and from one long radius (No. 2) of the *D* bolt showed roughened and fuzzy areas on the longitudinal surfaces as soon as they were cut that were still apparent after oven drying. In addition, some specimens showed marked bowing after they were oven dried (Fig. 5). The specimens from the short radii were smooth, with no rough or fuzzy areas and no bowing. These

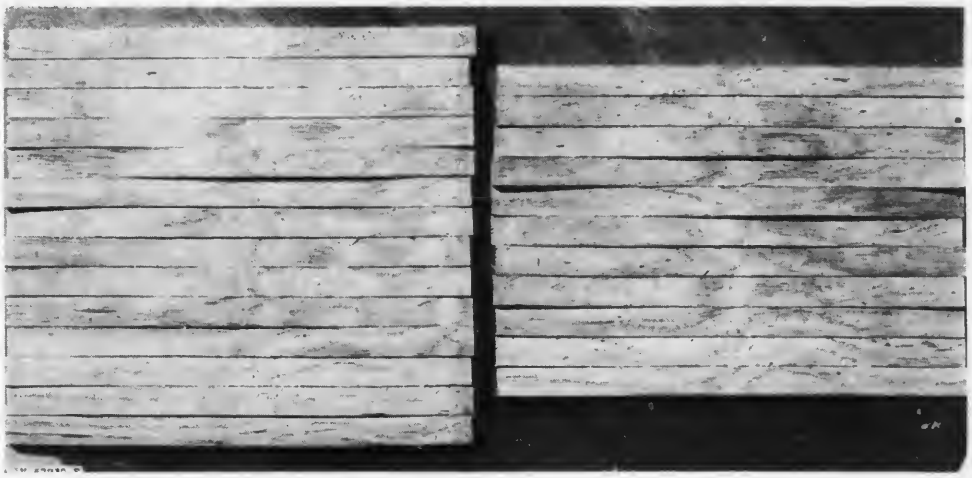

Fig. 5.—Longitudinal-shrinkage specimens from the long radii of a leaning white oak tree showing roughened and fuzzy surfaces and bowing after oven drying.

fuzzy or rough areas were apparently due to pulling or tearing of the gelatinous fibers in sawing the specimens, and the bowing was probably due to variations in longitudinal shrinkage through the thickness of the specimens.

Data on Longitudinal Shrinkage.—The data on the averages and ranges of longitudinal-shrinkage values and specific gravity are given for each radius in Table 3. The average longitudinal-shrinkage values for both of the long radii of the *A* and *C* bolts and for one long radius (No. 2) of the *D* bolt are appreciably higher than Koehler (*9*) considered normal for most species and than occurred in speci-

TABLE 3.—AVERAGE AND RANGE OF LONGITUDINAL SHRINKAGE AND SPECIFIC GRAVITY ON LONG AND SHORT RADII OF BOLTS FROM A LEANING WHITE OAK TREE

Bolt	Radius	Longitudinal shrinkage		Specific gravity	
		Average Percent	Range Percent	Average	Range
A	Long (1)	0.79	0.61–0.88	0.706	0.661–0.739
	Long (2)	.72	.44– .89	.691	.645– .747
	Short (3)	.15	.08– .24	.667	.578– .764
	Short (4)	.15	.07– .19	.686	.624– .833
C	Long (1)	.81	.76– .89	.680	.615– .746
	Long (2)	.77	.66– .82	.670	.571– .727
	Short (3)	.18	.15– .25	.663	.581– .704
	Short (4)	.15	.12– .18	.667	.621– .721
D	Long (1)	.28	.17– .46	.626	.587– .656
	Long (2)	.71	.59– .82	.625	.586– .707
	Short (3)	.18	.13– .30	.640	.574– .685
	Short (4)	.15	.12– .18	.652	.594– .686

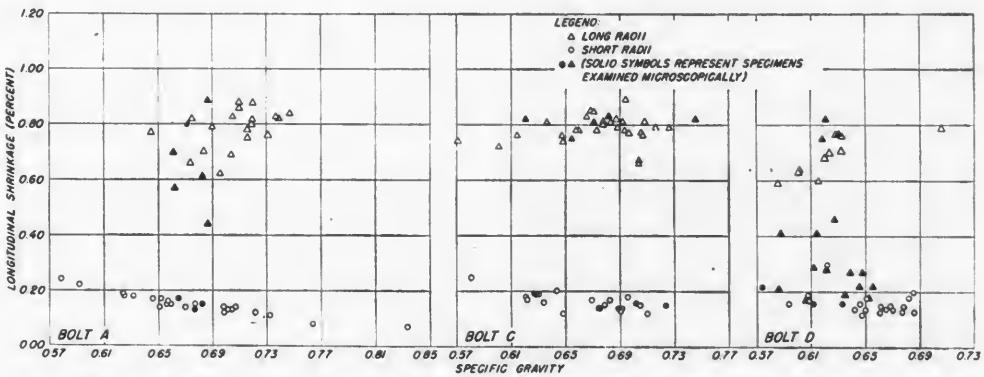

Fig. 6.—Relation of longitudinal shrinkage in percent of green length to specific gravity based on volume and weight when oven dry of specimens from long and short radii of a leaning white oak tree.

mens from the short radii. The shrinkage values found in some of the specimens from one long radius (No. 1) on the upper side of the *D* bolt, however, were intermediate between the high values generally found on the upper side and the low values predominant on the lower side with respect to the general direction of the lean in this tree. Fig. 6 shows graphically the relation of longitudinal shrinkage to specific gravity of specimens from the long and short radii of the *A*, *C*, and *D* bolts of the leaning white oak tree.

Occurrence in Relation to Longitudinal Shrinkage.—Some specimens from both the long and short radii of each of the *A*, *C*, and *D* bolts were examined to determine the amount of gelatinous fibers. The inner portion of the gelatinous fiber wall was visible as a thick and swollen layer that was frequently partially detached from the outer secondary wall. The lumen of the gelatinous fibers (Fig. 7) was small in size compared to that of normal fibers (Fig. 8), and at times the gelatinous portion was split into two layers. The normal fiber wall consisted of a middle lamella and a homogeneously stained primary and secondary wall, and the fiber lumen was fairly large and spherical

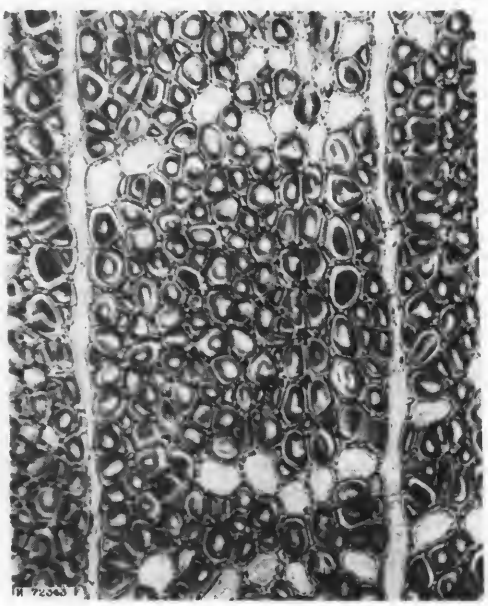

Fig. 7.—Photomicrograph of gelatinous fibers from long radius of leaning white oak tree.

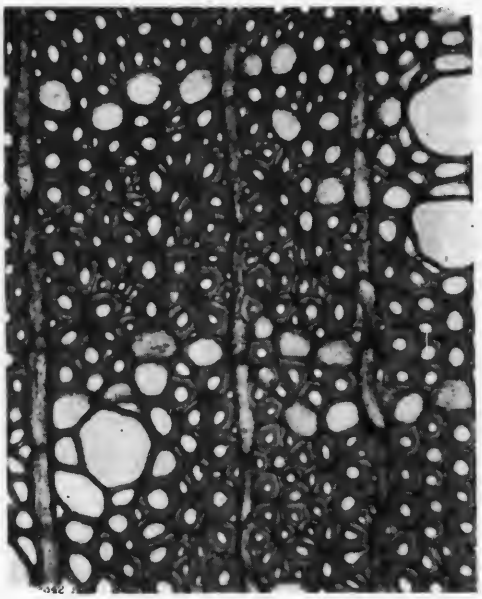

Fig. 8.—Photomicrograph of normal fibers from short radius of leaning white oak tree.

(Fig. 8). The numbers of gelatinous fibers varied greatly in the specimens examined microscopically; that is, in some specimens practically no gelatinous fibers were found, while in others almost all of the fibers were gelatinous. Each transverse section examined was visually classified as having no gelatinous fibers, or as having small, moderate, or large numbers of these fibers (Table 4).

Moderate to large amounts of gelatinous fibers and high longitudinal shrinkage were found on the long radii (upper side) of the *A* and *C* bolts, while no gelatinous fibers and low longitudinal shrinkage occurred on the short radii (lower side). The two specimens with moderate numbers of gelatinous fibers in these bolts had somewhat lower longitudinal-shrinkage values than those with larger numbers of such fibers.

The three specimens examined from long radius No. 2 from the upper side of the *D* bolt (18 feet above the ground) had high longitudinal shrinkage and large amounts of gelatinous fibers, while the three specimens from the short radii (lower side) had low longitudinal shrinkage and no gelatinous fibers. In contrast, the average longitudinal-shrinkage

TABLE 4.—SPECIFIC GRAVITY, LONGITUDINAL SHRINKAGE, AND ESTIMATED AMOUNT OF GELATINOUS FIBERS FOR EACH WHITE OAK SPECIMEN EXAMINED MICROSCOPICALLY

Bolt	Radius[1] and specimen Number	Specific gravity	Longitudinal shrinkage Percent	Estimated amount of gelatinous fibers
A	2–10	0.687	0.89	Large
	2–2	.672	.80	Large
	1–10	.661	.70	Large
	1–14	.683	.61	Large
	2–4	.662	.57	Moderate
	2–5	.686	.44	Moderate
	4–11	.665	.17	None
	4–10	.682	.15	None
	3–7	.677	.13	None
C	1–13	.682	.83	Large
	2–17	.621	.82	Large
	1–3	.746	.82	Large
	2–14	.671	.81	Large
	2–10	.655	.75	Large
	3–10	.627	.19	None
	3–7	.702	.16	None
	3–3	.724	.15	None
	4–4	.676	.14	None
	4–7	.689	.14	None
D	2–11	.622	.82	Large
	2–12	.631	.77	Large
	2–13	.619	.75	Large
	3–11	.574	.22	None
	4–4	.612	.16	None
	3–9	.633	.16	None
	1–1	.628	.46	Large
	1–2	.588	.41	Moderate
	1–12	.615	.41	Moderate
	1–13	.612	.29	Moderate
	1–11	.622	.28	Moderate
	1–9	.639	.27	Moderate
	1–10	.648	.27	Moderate
	1–7	.646	.22	Moderate
	1–5	.656	.22	Moderate
	1–8	.587	.21	Small
	1–4	.635	.19	Small
	1–6	.652	.18	Small
	1–3	.606	.17	Small

[1]Numbers 1 and 2 designate the long radii, 3 and 4 the short radii.

values of long radius No. 1 were considerably lower than those of radius No. 2 (table 3). In general, more gelatinous fibers were found in specimens having the relatively higher shrinkage values than in specimens having the lower shrinkage values, although some gelatinous fibers occurred in all the sections (Table 4). There was considerable variation in the location of the gelatinous fibers in these sections; often they were found only on one edge of a longitudinal-shrinkage specimen or were limited to one or two rings of a specimen.

It has been mentioned previously in the discussion of the eccentricity of the *D* bolt, that the lean of the tree probably changed between the levels at which specimens were taken in the *C* and *D* bolts, because the greatest eccentricity had changed from north-northeast and south-southeast in the *C* bolt to northeast and southwest in the *D* bolt. Since the longitudinal-shrinkage specimens from bolt *D* were cut from the same side of the tree as those from the *A* and *C* bolts, it was concluded that long radius No. 2 from the *D* bolt fell within the gelatinous-fiber area while long radius No. 1 was toward the edge of the zone of gelatinous fibers and slightly away from the region of greatest eccentricity. Consequently, the specimens from long radius No. 2 had high longitudinal shrinkage and large amounts of gelatinous fibers, while those from long radius No. 1 had small to moderate amounts of gelatinous fibers and considerably lower longitudinal shrinkage than that of specimens from radius No. 2.

The data obtained from this leaning white oak tree showed a general relationship between variations in the amount of gelatinous fibers present and the longitudinal shrinkage. Such fibers were found on the longer radii of the upper side and were absent on the shorter radii of the lower side, a fact that substantiates Rendle's statement (*11*) that they characterize tension wood. Specimens sawed from the radii of the upper side had fuzzy surfaces, while those from the lower side were relatively smooth. In this tree, the occurrence of gelatinous fibers was related to the direction of the lean and to eccentricity, as well as to excessive and erratic longitudinal shrinkage and fuzzy surfaces of the specimens.

Summary

Fibers with gelatinous-appearing inner walls are found in many hardwood species. The inner walls give a "cellulose" reaction with reagents and stains in contrast to the "lignin" reaction of the rest of the wall and of normal fiber walls. Areas of gelatinous fibers can sometimes be identified visually by the silky, lustrous, and fuzzy appearance of end surfaces of logs or lumber.

The occurrence of gelatinous fibers on the upper side of leaning tree trunks and branches has led to the use of the term "tension wood" to describe the type of structure peculiar to the upper (tension) side of inclined parts of hardwood trees. Although gelatinous fibers have been found most abundantly on the longest radii of eccentric annual rings, they also occur abundantly on the shortest radii of some eccentric logs and also in concentric logs.

Gelatinous fibers have been shown to affect adversely the maximum crushing strength of wood, but not necessarily other properties. Such fibers cause excessive longitudinal shrinkage of wood. Veneer with abundant gelatinous fibers buckled and split, which fact, together with the fuzzy surfaces, made it unsuitable for plywood faces.

Information available is not adequate to evaluate the seriousness of the defects produced by the presence of gelatinous fibers in forest products, nor to develop a practical means of identifying them in logs or lumber in order that defective material can be eliminated for critical purposes. Such lack of basic information points to the need for comprehensive investigations of the occurrence and structure of gelatinous fibers with respect to the lean and other growth conditions of trees, as well as in relation to strength, shrinkage, and other properties of the wood.

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Report of Inter-Society Exploratory Committee

THIS committee was appointed early in 1949 and consists of representatives of the six organizations listed at the end of this report. The task assigned to the committee was to study the possibilities and practicabilities of joint meetings between the Forest Products Research Society and other societies, associations, and committees concerned with wood utilization and wood research and to explore the opportunities for coordinated activities leading to the possible advancement of research and development in the field of forest products.

It is to be understood that none of the groups participating in the work of this Exploratory Committee is obligated in any way by the conclusions or recommendations of the committee. If action is taken by any organization as a result of the activities of this committee it will be purely voluntary and through the regular procedures of that organization. It is obvious that a committee such as ours can study and recommend but can in no way obligate or commit any of the several organizations it represents.

Action Recommended

In studying its assignment, the committee has reached the conclusion that joint activities of the following kinds could serve a useful purpose and be helpful in coordinating activities and promoting forest products research and development and the application of their findings:

1. Promotion of full understanding between the various organizations concerned of their respective fields of interest and activity.

This effort can help materially in the avoidance, so far as practicable, of unnecessary duplication of effort. A step in this direction will be the assembling of information on the policies, purposes, and fields of work of the respective societies or committees represented on our Exploratory Committee, as well as others interested in wood but not yet represented on the committee.

2. Arrange for the systematic interchange of information on locations, dates, and programs of proposed meetings of the various organizations, to avoid undue saturation of one area and neglect of others caused by several groups meeting separately in the same area within a short time and discussing more or less the same subjects.

With sufficient advance notice of proposed meetings, it will frequently be possible for those in charge of arrangements to develop plans for joint meetings and programs or otherwise to avoid seeming duplication of effort or competition. It is possible that the office of the Secretary of the Forest Products Research Society will be willing to serve as the clearing house for such exchange of information and help bring together those who may be planning similar meetings in a locality at about the same time.

There are many opportunities for local meetings arranged cooperatively by two or more societies. An excellent example of this is the joint meeting of April 13 and 14, 1950, in Washington, D. C., "for discussions on the subjects of greater mechanical efficiency in lumber manufacture and logging operations, woodcutting tools and equipment, use of machinery in forestry, and post-war developments in wood products research." This meeting was sponsored by the Wood Industries Division of the American Society of Mechanical Engineers, but staged in cooperation with the Washington Section of the American Society of Civil Engineers, the Forest Products Research Society, the Washington Section of the Society of Automotive Engineers, and the Society of American Foresters. The joint effort was much more favorable to complete participation of all who were interested in these subjects than the individual action of any single group would have been.

There is only limited opportunity for such correlation at national meetings because the national meeting of each Society or Association usually requires all the time available during the period of the meeting. To some extent, however, it is possible to call committee meetings of one society during or just before or after the national meeting of another society when mostly the same people are involved. For

example, it has become the custom to have a meeting of ASTM Committee D-7 at the time of the annual convention of the American Railway Engineering Association in March. Many individuals are members of both groups and can save time and expense when they are able to have more than one meeting at the same place during a short period of time.

3. Encourage the holding of joint symposiums between two or more of the societies for the comprehensive discussion of subjects of mutual interest.

These could be more technical and less popular in character than the local or sectional meetings referred to under item 2, and would appeal to smaller groups or to specialists in an individual field of research or development. For example, suitable subjects for a technical seminar of specialists would be the improvement of wood-cutting saws, the chemical utilization of lignin, or design stresses for timber.

4. Preparation of appropriate joint publications such as handbooks, pamphlets, or other types of publications where joint effort may be advantageous.

No such publication is now in prospect and there seems no immediate need for one. The committee anticipates, however, that sooner or later, good opportunities of this kind will develop in which two or more of the societies or their committees will find joint action desirable.

Policy Reaffirmed

In connection with items 3 and 4, reference is made to the 1949 report of the FPRS Committee on Coordination of Research. The Policy Statement, which was recommended by that committee and adopted at the Grand Rapids meeting of the Forest Products Research Society, contained the following among the seven means of facilitating the coordination of research in forest products:

"4. Increasing the availability of abstracts relating to forest products research and development.

5. Sponsoring the publication of monographs or reviews on specific subjects to review the current knowledge of each subject to provide a solid background for developing new projects, and to avoid useless repetition.

6. Sponsoring and encouraging round table meetings of experts engaged in or interested in specific subjects or lines of research, for informal discussion of their progress, methods, and problems."

These afford good opportunities for joint efforts or action by all the interested organizations.

It is the recommendation of this Exploratory Committee to the organizations represented in its membership and to all other organizations interested in wood utilization that these organizations endeavor, each in its own way, to facilitate cooperation and joint action along the lines indicated in the foregoing discussion, wherever it is practicable.

George M. Hunt, Chairman, Forest Products Research Society

Frank J. Hanrahan, American Society of Mechanical Engineers, Wood Industries Division

D. B. Mabry, American Wood-Preservers' Association

Herbert B. McKean, Society of American Foresters

G. M. Magee, Association of American Railroads

L. J. Markwardt, American Society for Testing Materials, Committee D-7

Wm. A. Oliver, American Society of Civil Engineers, Committee on Timber Structures

TECHNICAL SESSION VI

Wednesday, June 28, 1950, 9:00 A. M.

General Subject: Wood Particle Board

Chairman: C. C. Heritage, Director of Development, Weyerhaeuser Timber Company, Tacoma, Washington

Recorder: Clarence D. Stone, Elliott Bay Lumber Company, Seattle, Washington (Chairman, Pacific Northwest Section, FPRS)

C. D. Stone, C. C. Heritage

Hardboards From Wood Semi-Dry Process

H. R. Evans

Plywood Research Foundation, Tacoma, Washington

A semi-dry process for the production of hardboards developed by the Plywood Research Foundation, Tacoma, Washington, is described. Bark-free veneer waste, edgings, slabs and other wood wastes or residues can be used as raw materials. Chips are softened in a continuous steaming process and then defiberized. Small amounts of thermosetting phenol-formaldehyde resins and wax sizing agents are added to the chips during the softening process. Boards with properties similar to those made by commercial wet- and dry-felting processes can be obtained by this semi-dry process.

Introduction

THE semi-dry process for the production of hardboards, as herein discussed, was developed by the Plywood Research Foundation of Tacoma, Washington and differs from both the wet and dry processes now in commercial production. In the semi-dry process very little, if any, water is added to the green or uncured wood; and, unlike the dry process, it has not been found necessary to remove any moisture from the wood prior to processing.

The first full-scale production plant to employ the semi-dry process is now under construction, therefore no actual cost data is available and none will be given here. The said plant will employ one twenty-opening, 4-foot by 8-foot hot press "line" having a capacity of 75,000 square feet of one-fourth inch hardboard per day, utilizing waste from a Douglas fir plywood mill.

Type of Material

The type of materials that may be used in the production of hardboard by the semi-dry process range from veneer waste, and saw mill edgings to slabs, and in some localities woods waste, where the latter can be accumulated economically. The material should preferably be bark free. However, a small amount of bark may be used in certain types of hardboard.

Preparation of Material

The chipping, screening, conveying and storage of wood for the semi-dry process is the same as conventionally used in the present hard- and soft-board plants. Therefore, they will not be discussed in detail in this paper.

Cooking

In order to produce a suitable fiber for the manufacture of hardboard, it has been found necessary to steam or cook the chips prior to passing them through the mechanical defiberizers. This softening of the chips may be accomplished by steaming at atmospheric pressure or at higher pressures in a rotary digester such as is used in a conventional insulating board plant.

A preferred method is one employing a continuous cooker or steamer of recent design. Metered chips are fed into a rotary barrel-type valve which feeds the main tube of the cooker and the chips are then advanced through the main tube of the cooker by a series of adjustable paddles set at right angles to the axis. The retention time is controlled through the adjustment of the angle to which the paddles are set and by a variable-speed drive on the shaft of the cooker. Steam pressures from 20 to 50 psi. and retention times from 8 to 20 minutes are used to soften the wood chips for the production of a suitable fiber. This continuous method of steaming or cooking the chips is very advantageous as it provides a continuous, even flow of material to the defibrators at a controlled temperature. The out-feed end of the cooker is controlled by another rotary or barrel-type valve which discharges into a continuous mixer.

Additives

The additives, such as binder, size, or wax, are introduced into the continuous mixer where they are thoroughly brushed onto the chips. Normally from 1 to 3 percent, solids basis, of thermosetting resins such as phenolic and from 1 to 3 percent, solids basis, of a size such as

Paracol or Ceremul waxes are added. The binder and size are in an emulsion and if additional water is required, because of a low moisture content in the original wood, it may be added along with the emulsion.

An alternate method of mixing the additives is to take the chips directly from the cooker, pass them through the defiberizing machine and introduce the additives on the fiber; subsequently passing the fiber either through a continuous mixer or through an attrition mill equipped with special plates to disperse the additives on the fibers.

Defibrating

The coated chips being discharged from the continuous mixer are fed directly to defiberizing machines, such as the Bauer Pulper or the Allis-Chalmers Interplane Grinder. The type of plates used will vary somewhat in relation to the species of wood being ground and the class of fiber desired for a given product. In addition to the production of the fiber, these attrition type mills have proven very successful in dispersing the small amount of additives onto the fibers. Several tests using a water soluble dye along with the additives have shown complete dispersion through the coloring of the individual fiber bundles.

Conveying

The fibers upon discharge from the refiners are picked up in an air stream by a blower and discharged into a cyclone for air separation, with the fibers being fed directly to the felting machine. While this is a very simple step in the handling of the fiber, its advantages must be pointed out as against the conventional wet process where the fiber is handled in a slurry usually of a consistency under 4 percent. Thus, the semi-dry process eliminates the expensive equipment and the power necessary to handle the immense volume of water required in the wet process.

Felting

The machine developed for laying down a continuous mat of the semi-dry fibers has been appropriately named "Felter." The fibers discharging from the cyclone are fed by chute or belt to a high speed rotor in the felter and distributed by it to the top of the felter chamber. The fibers fall to the floor of the felter giving much the effect of a very heavy, gentle snow storm. The effect of this "snowing" action produces a type of fiber mat which has a great influence on the properties of the subsequent board. The floor of the felter is a moving belt which is synchronized with the output of the defiberizers. As the mat emerges from the felting chamber, it has attained a height or thickness in excess of that desired for the final mat. Such excess is removed and may be returned to the in-feed end of the felter. The mat emerging from the felter is 6 to 8 inches thick for a ¼-inch board and is preferably compressed so it will maintain a thickness of about 3 inches. The mat continues to advance on a belt past traveling saw mechanisms and is automatically cut into the desired lengths for pressing. The individual mats are then separated from each other on belts to facilitate rapid feeding thereof into the press loader or charger. A unique loader has been designed which loads on both its upward and downward travels. By this method the waste heretofore incident to the travel of a charger on its return stroke has been eliminated, thus shortening the cycle required for loading the press and returning the charger to the correct position for receiving the next batch of oncoming mats.

Pressing

With the exception of a greater daylight opening between the plates, a conventional 20-opening, steam-heated hardboard press is used for the pressing and curing of the mats. The mats are received on conveyer type wire cloth from the charger and carried onto the press plates. Stainless steel cauls are permanently suspended from the bottom side of each steam plate to produce a hard, smooth face on one side of the board. An initial high pressure of 500 to 1000 psi. is applied for a short period and thereafter the pressure is automatically decreased to a range of 125 to 200 psi. for the balance of the cure. The cycle runs from 8 to 12 minutes for a ¼-inch board. At the end of the holding cycle the boards are ejected or unloaded from the press by means of the conveyer type wire cloth which has remained under the mat during the pressing cycle to facilitate the venting of the moisture.

Humidifying

As the boards received from the hot press are very dry, they should be placed in controlled humidity and brought up to a moisture content of 5 to 7 percent before being packaged for shipment. Either the conventional tunnel type humidifier which requires stacking and stripping of the boards, or the wicket conveyor type humidifier may be used.

Tempering

Since our work to date on the process has been confined to pilot plant production of a standard board, the work on tempering has been relatively restricted. However, such work has been sufficient to indicate that certain consumer needs will require the tempering of a percentage of the production. This may be done either by introduction of additional resin in the process or by the addition of hardening oils to the surface followed by baking prior to humidification.

Properties

Properties of the boards produced under the semi-dry process compare very favorably with those of boards produced under the long established wet process. With flexural strengths on a board having a density of 1.0 falling into the 5000 to 6000 psi. range, a standard board made under the semi-dry process will have a twenty-four hour water absorption of about 16 percent and a thickness swell of about 8 percent, and an edge swell of less than one half of 1 percent. Standard boards with a density of 0.85 to 1.0 have extremely hard, abrasive resistant surfaces and have a light, pleasing color.

Mr. R. F. England (State of Washington Institute of Forest Products): Can bark be allowed in your process and if so, what are the optimum and maximum allowances?

Mr. Evans: Our data is based on bark free fibre. If color is no defect, various percentages of bark can be used.

Mr. A. Elmendorf (Elmendorf Research, Inc.): Have you any data on the difference in cost between the wet process (pumping) and semi-dry (air flow)?

Mr. Evans: I couldn't give you exact figures —the semi-dry process cuts down costs due to less original investment. The advantage of this process is that it is less expensive.

Mr. M. E. Dunlap (Forest Products Laboratory, Madison, Wisconsin): Is it possible to use species other than Douglas fir in the manufacture of hardboards by the semi-dry process?

Mr. Evans: Yes, other species such as spruce, pine, redwood, white fir and combinations thereof have been tried. If the pH is controlled, any species can be used.

Mr. A. L. Mottet (Long–Bell Lumber Co.): Is the one-percent to three-percent resin mentioned essential to the process or can an acceptable board be produced without resin as in the wet processes?

Mr. Evans: The properties are reduced with the reduction in resin content. You can make board without resins; however it will result in poor properties.

Mr. H. Garland (Michigan College of Mining and Technology): Have you used the so-called "McMillan" fibre in your research on this process?

Mr. Evans: No, it hasn't been tried.

Mr. E. Reichman (Simpson Logging Company): How well do Bauer Refiner Plates stand up under the dry grinding of wood?

Mr. Evans: Eight hours has been the longest continuous run. We don't have the complete answer.

Mr. Reichman: Is there any great difference in the type of refiner plate best suited for dry refining?

Mr. Evans: Standard plates will work. Some modification seems to be desirable.

Mr. C. M. Keaton (American–Marietta Company): Were the values given for moisture absorption for a 24-hour soaking period?

Mr. Evans: Yes.

Mr. Keaton: What were the resin contents of the boards?

Mr. Evans: There was two and one-half percent resin in boards tested at Oregon State.

FOREST PRODUCTS RESEARCH SOCIETY

Hardboard from Hardwood

Eduard Farber
Timber Engineering Company

Hardboards of medium density and hardness were produced from hardwood chips. These chips were treated by a chemo-mechanical process to obtain pulp of specified degree of fiber hydration. The boards were primarily designed for use as the face material of wirebound boxes and were found to perform satisfactorily.

General Principles and Special Cases

WHEN a new industry grows, there usually is an accompanying development of literature describing, protecting, or praising the new accomplishments. The literature of hardboard manufacture has been growing in direct proportion to the increase in hardboard production. In a search which was admittedly incomplete, the writer found about 45 United States patents on various compositions, methods, and machinery. The 1948 meeting of this Society was enriched by three reports in this field; one concerned a special method for fiberizing, another described the use of the disk mill to prepare materials for paper and board manufacture, and the third gave effects of variations in manufacturing procedures.[1]

A 1-day conference devoted entirely to wallboard was held last year under the auspices of the Northeastern Wood Utilization Council. The report about this conference has just been issued.[2] Another recent publication compares the characteristics of the wet process, in which the cellulose materials are used in the form of fibrous slurries, with those of the dry process in which wood particles are combined with resins.[3]

Surveys of materials, processes, machinery, and costs can be found in this literature. The purpose of the present paper is mainly to describe development of a special hardboard, its background and particular use. This development started out with a new method for converting hardwood waste into pulp. The special properties which distinguish hardwoods chemically from softwoods were put to use. Pulps were obtained in yields of 85 to 90 percent of the original hardwood substance. From this material a hardboard of medium density was produced for use as the face material of wirebound boxes.

Generally speaking, a variety of board can be obtained because the properties of the fibers can be modified by mechanical grinding and chemical additions, by combining or felting pretreated wood fibers, and by further treatment and conditioning of the materials thus produced. It is thus possible, through selected operations, to produce boards for different uses. In a new development there is a certain advantage in starting out with the aim of obtaining a board for a special application. It may be that with the great increase of interest in the manufacture of boards, specialization will take great strides in the future. Hardboard will then become a general name for a group of specifically different materials, although there might not be quite as much difference between them as between all the special kinds of plastics which are included under the general name of synthetic resins.

High Yield Hardwood Pulp

Methods for converting wood into pulp originally developed in two entirely different directions. By one method all the wood substance was utilized and disintegrated into fibers by wet grinding. By the other method, as much as possible of the noncellulose substance was removed from the wood, to the extent of losing a little cellulose in the process, so that the yields were 35 to 45 percent. The gap between these two methods began to be filled about a quarter century ago. At that time the

[1] "Proceedings, National Annual Meeting", FPRS Vol. 2 (1948), papers by U. Lowgren, p. 83; C. K. Textor, p. 89; H. D. Turner, J. P. Hohf, and S. I. Schwartz, p. 100.

[2] Northeastern Wood Utilization Council, Wallboard Production and Uses. Bulletin 31. New Haven, Conn. (1949)

[3] Armin Elmendorf, *"Wood"* 5 30. (1950)

first methods were described by the Forest Products Laboratory in Madison, in which only a part of the noncellulose was removed from the wood, and pulp was obtained in yields of over 65 percent. The new method developed at the Timber Engineering Company laboratory represents another step in the direction of reducing the extent of chemical attack on the wood in preparing pulp.

Hardwoods appear particularly suited for this step because they yield to certain mild chemical influences more readily than softwoods. The amount of substance which is easily solubilized by the action of steam, dilute acid, and dilute alkalies is considerably greater for hardwoods than for softwoods in general.

By removing only between 10–15 percent of substances soluble under mild chemical action upon hardwood chips, the wood could easily be separated into its structural fiber elements. The chemical pretreatment has at least two functions in the production of this pulp. The energy required for this separation of the fibers is reduced, and kinds of fibers result which have the complex affinities for water and properties of felting essential in board making. This way of describing some of the effects of the chemical pretreatment is not very chemical itself. For the present purpose it is not necessary to penetrate very deeply into the complexities of hemicellulose chemistry. It may suffice to mention that the chemical action on the cellulose content makes itself felt in the particular kind of contraction and hardening of such pulp on drying.

The influence of chemical pretreatment manifests itself during the fiberizing operation in the strength of a sheet of the pulp obtained with relatively low power consumption. When wood chips are passed through a disk mill, the intricate actions of rolling, grinding, crushing, and cutting are governed by the form and distance of the rotating grooved plates, the temperature of the shower water, and particularly by forces that hold the fibers together in the wood. When these latter are appropriately reduced, the energy supplied to the disk mill will not be spent to an undesirable degree on crushing and cutting. By thus concentrating the energy on the desirable part of the action on wood chips, an increase in energy consumption will improve the pulp properties; for example, with chips from mixed hardwoods after the mild chemical pretreatment the results given in table 1 were obtained, using a Bauer disk mill at zero opening and 107° F. shower water.

TABLE 1.—COMPARISON OF POWER CONSUMPTION WITH PULP SHEET PROPERTIES

Power.....H.P. days/ton	22	12
Freeness, New Green.....	411	680
Mullen bursting strength, percent....	17.7	6.15
Tearing strength, percent.....	3.9	5.3

Pulp and Board

The role of water in such a grinding operation is of a very complex nature. The water in which the chips and the fibers are suspended is not only an inert carrier, nor is it only a cooling medium to dissipate the applied energy in the form of heat. There is a definite exchange of chemical material between wood fiber and water. To understand this, it may be helpful to recall the experiments which show that cellulose, suspended in water containing heavy water, in a surprisingly short time contained some heavy hydrogen acquired by exchange of hydrogen between the cellulose and the heavy water.[4]

In paper maker's language, hydration indicates a relationship between fiber and water which goes just a little beyond mere physical absorption. A measure for this relationship is the rate at which water drains from the fiber slurry. This rate is designated as freeness. Pulp of high freeness is desirable because this means easy and speedy removal of water to consolidate fiber. High freeness has to be combined with good formation of the fibers to produce a strong sheet. As usual, in practical application we have to try to reach a balance. For best results we have to be satisfied with a medium degree of freeness in order to obtain a pulp of sufficient strength. When water leaves the fiber slurry too readily, in many cases the fibers are insufficiently interlocked to form a good bond. A medium degree of freeness, measuring between 600 and 700 in the Schopper–Riegler scale, is used for the main part of the pulp in the furnish.

When wet grinding or hydrating of wood fibers is continued to a much higher extent, the pulp becomes increasingly less free, so that

[4] Frilette, V. J., J. Hanle, H. Mark. 1948. Jour. Am. Chem. Soc. *70:* 1107.

finally the drainage is very slow. Usually, a very slow pulp is undesirable, because it cannot be handled on high-speed machines, or it would require a considerable increase of filtering surface on the machine. However, such very slow pulp has the desirable property of developing great strength on drying. It can be compared to a gelatinized starch and has, therefore, been called gelatinized wood (or gelwood). The merit of such gelatinized wood as a binder in board making was discovered by Howard Weiss.[5] The addition of a small percentage of this material to pulp of high freeness reduces the freeness somewhat, but not critically, and produces increased strength in boards made from the developed high-yield, hardwood pulp developed by the Timber Engineering Co.

Manufacturing Procedures

The basic ingredients for making these boards are a high freeness pulp combined with a small proportion of very slow pulp. Both are obtained in the form of slurries containing between 2 and 5 percent wood fibers. Boards made from such a composition have insufficient water resistance. This can be improved by adding water repellents. For example, paraffins or asphalt added in amounts of 2 to 5 percent of the dry weight of the pulp will reduce the water absorption considerably. When light color is not a primary requisite, asphalt, in the form of emulsions, can be used. After adding the emulsion to the fiber slurry, it is necessary to demulsify by means of alum or, generally, by producing a slight degree of acidity which does not have to be below pH 5.5.

Once the composition of the chemicals has been decided upon, the manufacturing procedure is relatively simple. The slurry is placed on a dewatering screen, subjected to pressure in order to remove free water, and finally dried. In the laboratory and in relatively small-scale production, this can be done on batch filters to obtain a wet mat, with subsequent pressing of these mats on forming screens separated by plates. Several kinds of machines are available to carry these procedures out in continuous operation. Ingenious devices have been constructed for automatic pressing and drying of such boards.

The use of very free and very slow pulp in mixture is only one example of the possibilities of manufacturing procedures. With the same kind of hardwood pulp as the basis, other materials than slow pulp (gelwood) can be used to obtain the desirable degree of formation and strength. Synthetic resins can be used. It is not only the high cost of these resins which demands that the quantities be restricted to very low proportions; in addition, boards made with relatively large proportions of synthetic resins, while of great hardness, may show increased brittleness. Melamine resins used in proportions of only 1 to 3 percent have proven efficient as binders without giving objectionable brittleness.

All pulp from hardwoods is short-fibered. It is advantageous to add some long-fibered materials where high elasticity and strength are required. The influence of fiber length on strength properties is another of those complex relationships which have been mentioned before. For straw boards, Lathrop[6] was able to show a very definite correlation between strength and length of fibers and, particularly, to select the appropriate proportions for optimum results. For fibers of other origins, not only the length, but the felting properties, and something that can only be vaguely described as affinity to the hardwood fibers are to be considered. For our purpose, mixtures of 80 pounds of our hardwood pulp with 20 pounds of a kraft-type softwood pulp proved highly satisfactory, particularly when combined with gelatinized wood made from the hardwood pulp.

Testing Procedures

I mentioned at the beginning that this particular hardboard was to be used as the face material for wirebound boxes. The tests were designed to indicate those properties which most likely would be important for this special use. The goal was to reach the strength properties of gum veneer. This therefore served as the basis for comparisons.

[5] Weiss, Howard. U. S. Patent Nos. 1,631,171, 1,631,172 and 1,631,173.

[6] Lathrop, E. C., T. R. Naffziger. 1949. Tappi 32: 309–30.

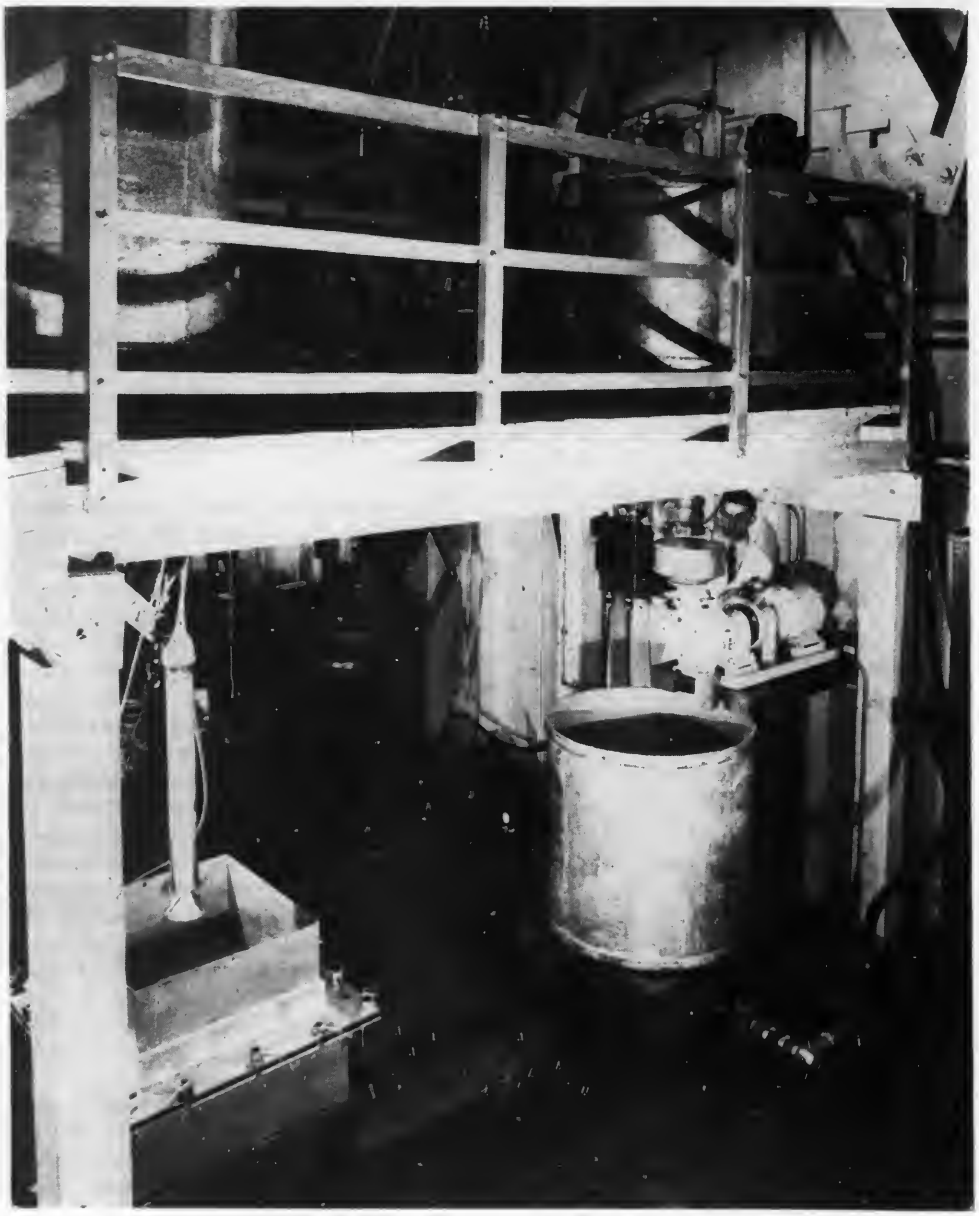


Fig. 1.—Pilot plant for pulp and board making.

The main strength tests were those for static bending, toughness, and staple-holding. These tests were designed to approach conditions significant for the endurance of a box. A short span was therefore used in bending, and the behavior of the board in stapling it to wood was investigated. Strength and resilience are thereby measured.

Static Bending Tests

Pieces 4 by 6 inches were tested over a 4-inch span in a Baldwin–Southwark testing machine. The load was applied in the center of the span at the rate of 0.1 inch per minute. The end point was defined as a definite failure of the test piece. The maximum load at this point was determined.

Toughness

Specimens 5/8 inch wide and 10 inches long were tested over a 4-inch span in a machine built according to the Forest Products Laboratory design. The load was applied by means of the free-swinging pendulum. The energy absorbed in breaking was measured in terms of foot-pounds.

Staple Holding

The staple-holding test was designed to measure the lateral load required to pull staples driven through the board into a wooden cleat. The piece of board 2.5 by 4 inches was connected to wood by staples made from wire of 0.063-inch diameter. Two staples, each 5/8 inch away from the edge, were driven straight into the cleat by hand. A piece of wire positioned under the staples had a diameter of 0.081 inch. This assembly was clamped in the testing machine. The rate of pull was determined by a platen speed of 0.025 inch a minute. The load at the point of failure was registered. In most cases failure consisted in the pulling of the staples through the board. Sometimes tension failure between the staples was observed.

In addition to these tests, which were amplified by other special arrangements and by the usual kind of water-absorption measurements, a nondestructive test based on determination of resonant frequencies was developed. The assembly used is shown in Fig. 2.

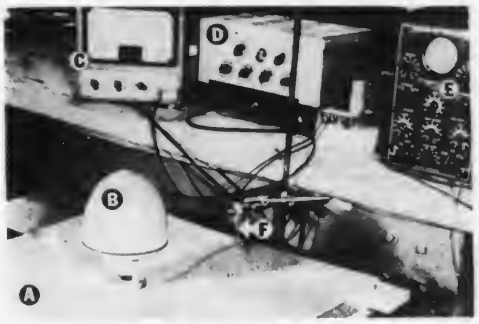


Fig. 2.—Apparatus for determining resonant frequency of fiberboards. *A*, board being tested; *B*, electrodynamic vibrator; *C*, audio oscillator; *D*, power amplifier; *E*, oscilloscope; *F*, crystal pickup.

Influential Factors

The most desirable board is one which combines high strength in bending with great toughness, and can be manufactured at low cost. Usually, however, when testing modifications, it will be found that those which increase strength in bending will tend to reduce toughness. The accompanying table 2 shows some of these results.

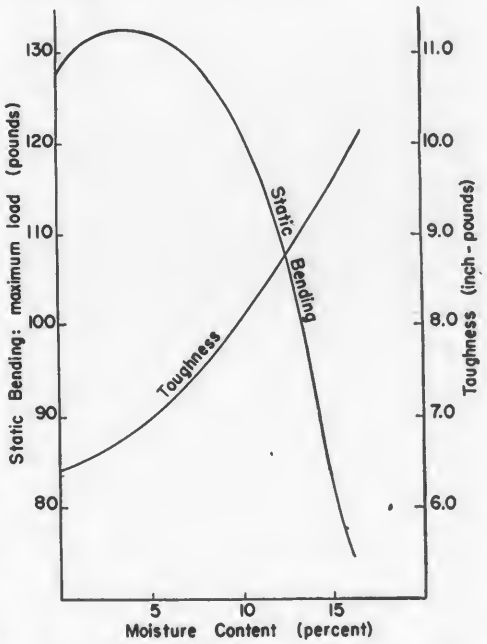


Fig. 3.—Change in static bending strength and toughness of hardwood pulp boards with moisture content.

TABLE 2.—COMPOSITION AND CHARACTERISTICS OF HARDBOARD

Specimen number	51	58	216	220	gum veneer
Pulp	Teco	Teco	Teco and 20% Kr	Teco and 10% straw	-------
Binder	15% gelwood	3% melamine resin	10% gelwood	10% gelwood	-------
Thickness	0.170	0.170	0.195	0.200	0.125
Spec. grav.	0.75	0.75	0.74	0.71	0.525
Weight, grams per sq. ft.	293	306	339	336	146
Maximum bending load, pounds	116.0	117.0	104.0	98.0	170.0
Toughness, inch-pounds	6.64	6.51	6.94	6.14	9.60
Water absorption, percent:					
2 hrs.	10.3	10.6	14.4	15.6	-------
24 hrs.	34.2	41.4	44.5	55.3	-------

Moisture content also has a decided influence on these strength properties. Fig. 3 gives an example for the increase in toughness, accompanied by a loss in bending strength when moisture content is increased.

Performance Tests

The ultimate test for boards of this kind is their performance in actual use to make wire-bound boxes. In this kind of box, panels are combined with wires and staples which are held to wooden cleats in the manner illustrated in Fig. 4. A great number of such boxes were

FIG. 4.—All-bound box made of Teco hardwood board, shown after 73 falls produced final failure.

made in the Package Research Laboratory of the Stapling Machines Company, Rockaway, New Jersey, loaded in accordance with special experiences of the Package Research Laboratory, and tested by tumbling in a 14-foot drum provided with specially designed hazards. The number of falls until failure begins and, after continued tumbling, until a definite break occurs are recorded. One of the results obtained with particular compositions of board for the face materials is represented in Fig. 4. It will be seen that some of these boards perform very well. The correlation between the tests of actual performance and the single quality tests on specimens is shown in Table 3.

Forests and Industries

The question may be asked why, in this particular case, a so-called synthetic board should be developed and investigated when it is known that the material for this application can be produced by converting logs into veneer. The reasons are manifold and connected with a number of technical and commercial aspects. When we produce synthetic rubber, even at times when natural rubber is available, we try to accomplish at least two purposes. One is to be independent of supplies from crops and influences of such complex nature as weather and transportation. The second purpose is to produce materials in which properties can be variously combined and qualities improved. This is only an example; not all features which characterize it can also be applied to our present case. While the raw material used for synthetic rubber has nothing to do with that for natural rubber, our raw material for synthetic boards is in substance the same as that for what may be called the natural board for which veneer is used. The same in substance does not mean the same in availability and value. We start from the by-product necessarily produced when using trees to make lumber, veneer, and manufactured materials. While situations may arise, and have arisen, in which the natural material, veneer, is in short supply, the by-product for the synthetic material will always be available as long as the main products are being made. With respect to that second purpose mentioned above, the situation for the synthetic board is much more nearly comparable to that described for the synthetic rubber. The effort of synthesis starts with the goal of obtaining a material that is equivalent to the natural

TABLE 3.—RESULTS OF ROUGH-HANDLING TESTS ON ALL-BOUND BOXES MADE OF TECO HARDWOOD PULP FACE BOARDS[1]

Board characteristics:						
Binder used	Gelwood		Gelwood and Kraft	Melamine resin	
Thickness average, inches	0.191	0.182	0.141	0.219	0.223
Weight M.S.F., pounds	685	765	584	824	893
Specific gravity	.69	.80	.77	.75	.87
Flexural tests, 3" span:					
Max. load, pounds	94	105	34	160	162
Puncture test, G.E. units	990	990	602	1,020	1,272
Boxes:					
Test loads, pounds	150	150	100	150	150
Number of falls:					
Air-conditioned:					
First serious failure	23	46	25	19	43
Final failure	50	83	35	31	61
Conditioned at 85° F. 92% R.H.					
First serious failure	-------	-------	48	----------	94
Final failure	-------	-------	48	----------	108

[1] Inside dimensions of boxes: 20"x16"x12".

one; then, however, avenues are opened up which lead to possibilities of further improvements.

Acknowledgment

The development of this hardboard was sponsored by the Stapling Machines Company.

The stimulating interest of Henry Wolsdorf, Vice President of the Stapling Machines Company, and the permission to publish this report are gratefully acknowledged. Matthew Sciascia, of the Timber Engineering Company staff, had a prominent part in carrying out this work.

Discussion

Mr. E. Mörath (Food and Agriculture Organization of the United Nations): The international cooperation in the field of fiberboards and wood particle boards demands a better understanding with regard to the terminology and a unification of the testing methods. The Division of Forestry and Forest Products of FAO is preparing an international investigation on this subject and requests the help of the gentlemen present whom I shall contact directly.

Mr. Farber: In my oral presentation I have deviated considerably from the printed text to put more emphasis on some of the fundamental aspects. I shall be glad to help in further clarification of terminology and unification of testing methods which are so essential for further progress.

Mr. R. C. Fraunberger (Philco Corp.): What properties could be specified for the ideal hardboard?

Mr. Farber: General factors to be considered are the following: 1. Pleasing appearance. 2. Strength adapted to specific application. 3. Dimensional stability. This is not necessarily the order of importance of these factors.

Mr. J. A. Hall (Pacific NW Forest Experiment Station): What about species variation in hardwoods especially with respect to variations in hydratability and extractives and the possibility of mixed boards of conifer and hardwood using hardwood fiber for hydration.

Mr. Farber: There are differences in ease of hydratability between softwoods and hardwoods. Hardwoods, after at least mild chemical preparation, without removing much of the hemicelluloses, usually hydrate more rapidly and form stronger bonds on drying.

Mr. A. H. Rauch (Plywood Research Foundation): Approximately what percent of "gelatinous wood" would be required in order to realize a hardboard having a specific gravity of about 1.0 and a modulus of rupture in bending of 5,000 psi.

Mr. Farber: Between 10 and 20 percent in the total furnish.

Mr. E. Clapperton (Western Pine Association): Are we approaching a saturation of the market for hardboard materials?

Mr. Farber: In most regions we are still far from saturating markets. Opportunities for special grades of boards are just beginning to be developed.

Mr. R. W. Miller (Simpson Logging Co.): What dimensional stability to water vapor is obtained from use of hardwood as contrasted with softwood (coniferous)? Does the pentosan content of a fiberboard affect its dimensional stability to water vapor?

Mr. Farber: Dimensional stability to water vapor is more a function of density and fiber coating than of pentosan content. The irreversible part of the drying in manufacture also has to be considered.

Mr. A. K. Esterer (Weyerhaeuser Timber Co.): How do you define toughness and how is it measured?

Mr. Farber: Toughness is the resistance to sudden energy loads. It is measured as the energy required to produce sudden break of a sample of specified dimension.

Mr. A. L. Mottet (Long–Bell Lumber Co.): Your paper attaches a great deal of importance to hydration in the formation of fiber bonding in hardboard. Some manufacturers of wet process hardboards attribute the bonding to "activation" of the lignin and plastic flow of lignin under heat and pressure in the pressing operation. Do you consider this latter action to play any important role in your hardboard?

Mr. Farber: No, cellulose makes a fine board. However, the question brings to light an important factor. It would be interesting to determine the basis for explanations which use plastic flow of lignin which, at present, is done more or less as conjecture. We know that certain kinds of lignin undergo irreversible changes under the influence of heat, particularly when combined with pressure. I suggest that somebody should investigate the chemical conversion connected with hardboard molding, with attention to the possibility that it is not the lignin alone, but part of the entire wood substance which is chemically modified.

Mr. E. G. Stern (Virginia Polytechnic Institute): Can you give cost data of hardboard vs. veneer faces for wirebound crates?

Mr. Farber: It is difficult to give prices for veneer right now. Manufacturing cost of hardboard from hardwood waste material is estimated at from 15 to 20 dollars per thousand square feet, at $\frac{1}{8}$-inch thickness.

FOREST PRODUCTS RESEARCH SOCIETY

Small Plant Set-Up for Insulation and Hardboard Manufacture

R. T. DePan

Development Engineer, Downingtown Manufacturing Company, Downingtown, Pennsylvania

Planning a small plant for making hard or soft board entails taking cognizance of quite a number of factors. There are several different processes used employing various types of equipment. The selection of the proper process calls for a study of the raw materials including their adaptation to board manufacture, cost of the plant, the manufacturing cost of board and the possibility of a steady market for the finished product.

Introduction

CONSIDERABLE interest has been shown in this country in recent years in processes and equipment for the manufacture of insulation board and its somewhat denser counterpart hardboard. This interest has been stimulated to a great extent by the increased demand for low cost building materials, by the increased difficulty in obtaining first-grade peeling logs for plywood manufacture, by the increasing awareness of lumber mills and wood using industries of the need or desirability for utilizing waste and trim, and by the definite trend toward conservation and the necessity for more efficient utilization of one of our natural resources, the forests.

Insulating Board

The term insulating board as considered here indicates a porous rigid board composed of wood or vegetable fiber material. Although its insulating value decreases with increase in density, strength requirements place the lower limits of its density in the range of 14 to 20 pounds per cubic foot. Commercial thicknesses are usually 1/2 inch for wall panels, planks and tiling, up to 25/32 inch for sheathing purposes. Some 3/8-inch board is being made and laminated products up to 4 inches thick for roof insulation are also produced.

Due to the multiplicity of raw materials used there are numerous processes for the manufacture of insulating board, but only those utilizing wood in some form or another will be discussed. Also, processes producing less than 50,000 sq. ft. per day will not be considered.

Stock Preparation Methods

There are usually two broad methods for producing fiber for insulation board purposes, namely by grinding or by use of attrition mills of some sort.

Grinding

Perhaps the greatest percentage of fiber produced for insulating board is made by grinding the wood. Grinders may be of the pocket or magazine type. Wood bolts about 30 inches long and 4 inches to 20 inches in diameter are placed parallel to the face of the grinding stone with the long direction of the wood parallel to the shaft of the grinder. The stone of a specially designed abrasive travels at high speed. The wood is pressed to the face of the stone by a ram until it is ground into small fibers or fiber bundles. Water is played on the surface of the grindstone to prevent the wood from burning and to wash away fibers already ground. Wood for grinding is usually in the green state and is sometimes soaked in water or weak chemical solution before being ground. Grinding has a high production for unit cost of equipment but is limited to the physical size of the stick it uses. At present, work is being done on the grinding of chips and if it proves practical will enable insulation board manufacturers to use waste and small sticks in their process.

Attrition Mills

Asplund Defibrator. A continuous type of fiberizing machine used both in this country and abroad is the Asplund Defibrator. Wood chips are pulped in the Defibrator at elevated temperatures in a steam atmosphere correspond-

ing to pressures between 125 and 175 psi. The wood chips are continuously introduced into a high-temperature preheating chamber by means of a screw or plunger feed. Heating by saturated steam at temperatures ranging from 350° to 370° F. causes softening of the binding substances between the individual fibers. After passing through the preheating chamber, the heated chips are conveyed to the attrition disc while still under pressure. Here separation of the fibers is effected by passing the chips between a rotating and a stationary disc. After defiberization the pulp is blown from the defibrating chamber through reciprocating or nozzle valves to a collector under atmospheric pressure. A Defibrator may be expected to process 10 to 30 tons of dry wood per 24 hours depending on the type of wood and the degree of fiber separation desired. Asplund fiber may be further refined, after defiberization. For use in insulation board in this country Asplund fiber is usually mixed with groundwood or fiber produced by other types of attrition mills. It may be refined and used to the extent of 100 percent in board if so desired.

Other attrition mills. Other types of equipment for producing insulation board fiber from wood include the Bauer pulper, the Allis–Chalmers Interplane Grinder, the Sprout–Waldron Refiner, the McMillan Machine, the Elmendorf Defiberizer, the Weinerfiner and hammermills. The Bauer pulper has the greatest usage in the mills in this country. This is a double-disc machine in which both discs are rotated. Stock is fed to the center of the discs through an opening in the center of one and is discharged at the periphery.

For defibering wood for use in insulation board it may be advisable to cook it in some manner. A mild treatment may consist of a steaming at atmospheric pressure or a soaking in boiling water. A harsher treatment is effected by steaming under pressure and the time of steaming will depend on the type of fiber used and the end product desired. The treatment may vary from a few minutes steaming at 300 psi. to 120 minutes steaming at 30 psi. Very usable fiber is prepared from chips steamed for 15 minutes at 100 psi. Spruce, balsam fir, aspen and some of the pines in green or water soaked condition are being converted with disc refiners without any pretreatment at all. Power consumption on the above varies from 30 to 12 hp. days per ton. A Bauer pulper will therefore produce 10 to 25 tons per 24 hours with an input of 300 hp.

Cooking Equipment

For cooking the wood, rotary or stationary digesters may be used. The rotaries are most common and range in size from 12 to 18 feet in diameter. A 16-foot globe rotary will hold 8 cords of chips. Birch, a heavy hardwood, can be cooked to a yield of 85 percent at the rate of 10 cycles per day or a capacity for the 16-foot digester of 125 tons.

Forming Methods

There are several types of machines for continuously forming insulation board. They are namely the double cylinder type of machines, the single cylinder type, and the fourdrinier type.

The two-cylinder machine was one of the earliest successful machines in commercial operation. A large wire-covered cylinder 6 or 8 feet in diameter is supported in a vat with a similar cylinder supported above it at an angle of about 45° also dipping into the vat, material from which is carried upward to form a considerable hydraulic head on the two cylinders. Half of the finished sheet is formed on each cylinder and the two parts are pressed into one board on leaving the nip of the cylinders. The board then goes to a press section before drying.

The single-suction cylinder picks up the sheet by vacuum created by a barometric leg and a vacuum pump. Consolidation of the sheet is assisted by means of press rolls mounted on top of the cylinder mold. The board then goes to a press section before being dried.

The fourdrinier forming machine is somewhat similar to the conventional fourdrinier except that the forming and press sections are combined. One wire passes over the board forming section through the presses so that the board is undisturbed before going to the dryer. A top wire or felt is used on the press section.

The press section for continuous forming machines will vary considerably depending on the draining characteristics of the sheet and the speed desired. The number of presses may vary from two to ten and may be either plain or

suction on top or bottom or both. Suction slices may be placed in back of the presses to remove the pond of water accumulated there. Spring or pneumatic loading may be used. Press sections may be non-cantilevered or fixed or adjustable cantilevered. Presses are equipped with stops to regulate clearances between the rolls. Fig. 1 and Fig. 2 illustrate possible variations in press sections.

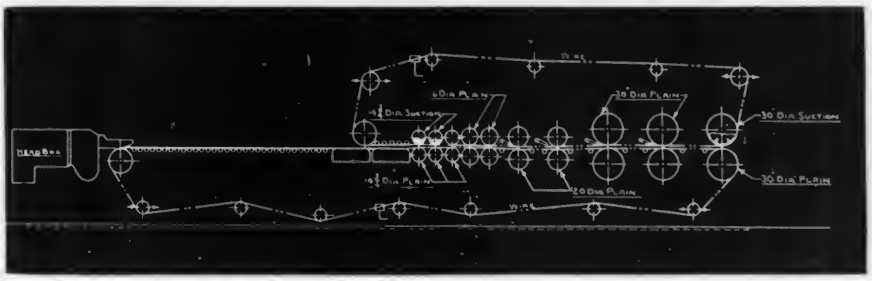


Fig. 1.—Elevation of 170-inch wallboard machine used for insulation-board manufacture.

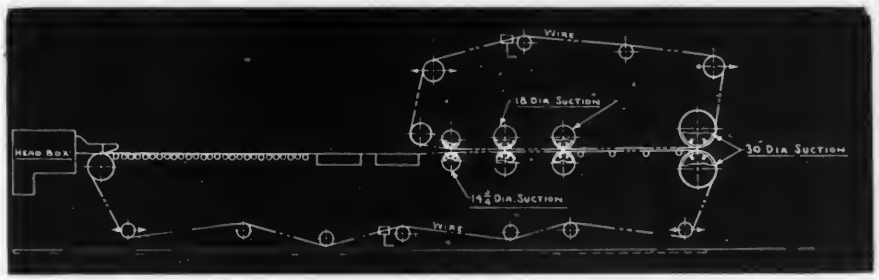


Fig. 2.—Elevation of 120-inch wallboard machine used for insulation board manufacture.

Drying Methods

Owing to the thickness of the board it must be dried in a flat condition and four different methods are used. These are (a) multiple-deck hot platen driers, stationary, (b) multiple-deck hot platen driers moving, (c) tunnel driers, and (d) multiple-deck continuous roller drier. The last type of drier is most widely used in this country.

Flow Diagrams of Wallboard Systems

Fig. 3 illustrates three typical set-ups for the manufacture of insulation board in this country. For production of good quality board at a fair rate of speed it is essential that the fiber mixture consist of a mixture of long fibers for structure and ease in drainage and short fibers for the strengthening characteristics. There is, of course, a medium wherein the greatest percentage of the fibers can be approximately of the same length. Development of the fiber must be to such a degree that the board possesses the necessary strength characteristics commensurate with the desired draining qualities and bulk factors. Appearance of the board itself is also quite important. In the examples shown, one method frees up the normal groundwood furnish with some long fibered Asplund fiber. In another method this freeing up of the groundwood pulp is accomplished by using Bauer-refined stock. The third method uses an admixture of Asplund fiber and Bauer stock refined to different degrees and freenesses.

Hardboard Manufacture

Within the past few years there has been considerable interest shown in the manufacture of hardboard in this country and abroad. Part of this is due to the recent expiration of certain basic patents.

There are numerous processes for the production of hardboard as such. Some of these utilize some form of binder and as a base material sawdust, shavings or fiber produced by other than attrition mills. These are so called "dry

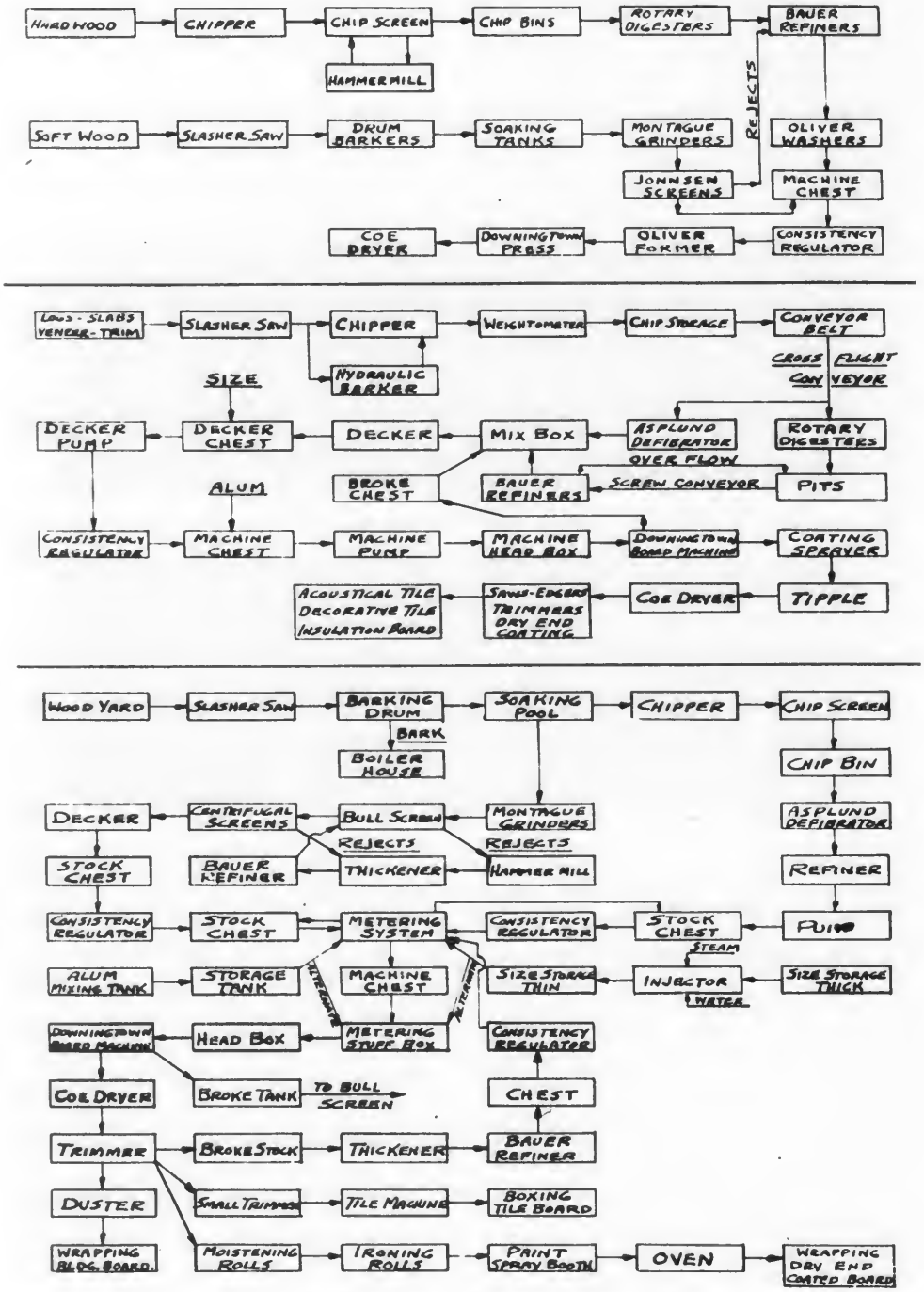


Fig. 3.—Flow diagrams of insulation-board mills.

processes" in that the material to be molded is spread into the molding trays as a dry mix and not suspended in a water medium. There are numerous variations of this "dry process", which will not be discussed at this time.

Hardboard as it is popularly known on the market is commercially produced by two methods. These two methods are similar in most of the steps of manufacture.

Wet Process Hardboard

In this method of manufacturing hardboard (see Fig. 4) the fibrous mat formed by draining a fiber suspension in water is pressed in a heated platen press while still containing about 50 percent water. Pressures used vary from 425 to 850 psi. depending on the type of wood used. It is customary to use a high pressure for the first part of the pressing cycle and then decrease it during the latter part. Temperatures used approximate 350° to 400° F. Time for a complete cycle will vary slightly but will approach 15 to 20 minutes.

The wet process for making hardboard was originated by Mr. Mason approximately 25 years ago. The Masonite Company utilizes a process for producing fiber that involves high pressure steam treatment followed by a quick release of pressure. Both hardwoods and softwoods are used and, though usually barked, may be used with the bark. The five-foot bolts of wood are chipped into pieces approximately ¾ inch square and, after being screened, are fed into a battery of 20-inch-caliber guns. A gun is filled and closed and steam admitted until the pressure registers 1,000 psi., equivalent to 550° F. or 285° C. After being held at this point for a few seconds the bottom valve of the gun is opened and the chips exploded against a target into a brown fluffy mass of fiber. Entering a cyclone the steam is let off and condensed and the exploded fiber falls into a stock chest where it is mixed with water and pumped through washers, refiners and screens. Forming is accomplished on a fourdrinier-type machine after which the board passes between roll presses and then into a platen press for final pressing. The end product is very sensitive to the steaming time, which is dependent on the type of wood and the size and moisture content of the chips.

Other common methods for making fiber for hardboard are by use of the Asplund Defibrator followed by a refiner or by use of the Bauer refiner preceded by a cook of some sort. Tonnages and degree of fiber reduction can be varied by varying disc setting and cooking time.

Methods for forming the hardboard mat are continuous-forming by means of the fourdrinier former or the suction cylinder, and batch forming in large sheet molds. This latter method of forming is usually adapted to lower tonnages than is the continuous system. The wet batch process for hardboard as used on the West Coast is known as the Chapman Process and the major steps are shown in Fig. 5.

Pressing of the wet mat, in the continuous system is accomplished by means of a series of roll presses, some of which may be suction rolls. Pressing of the mat formed by the batch method is usually done with a platen press. Pressing of the wet hardboard sheet does not present much difficulty as the fibrous mat is quite free and loses water readily. Fig. 6 shows a typical machine for forming and pressing hardboard.

After pressing, wet process hardboard made by the continuous system is cut into suitable lengths and is moved into a press loader. This

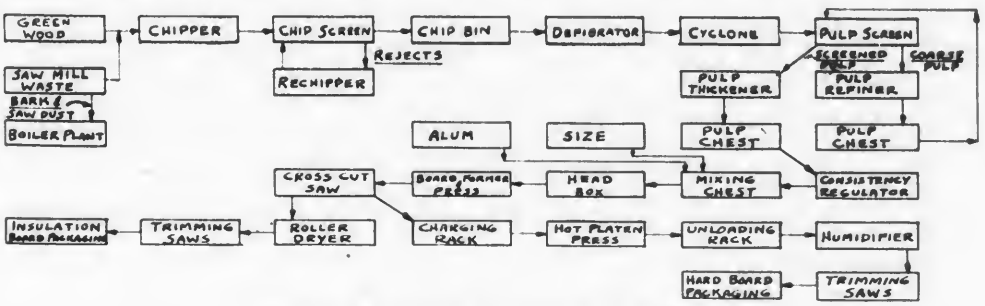


Fig. 4.—Flow diagram of wet process for hardboard.

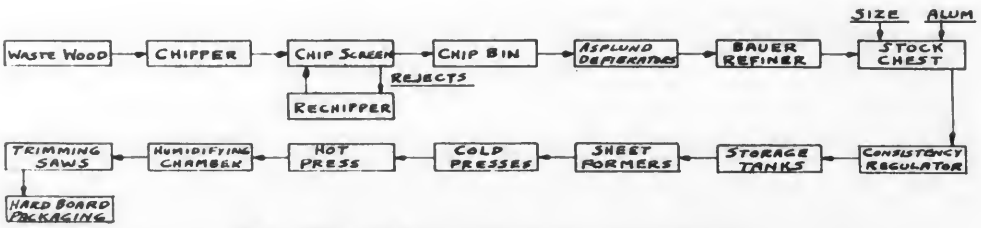


Fig. 5.—Flow diagram of Chapman process for hardboard.

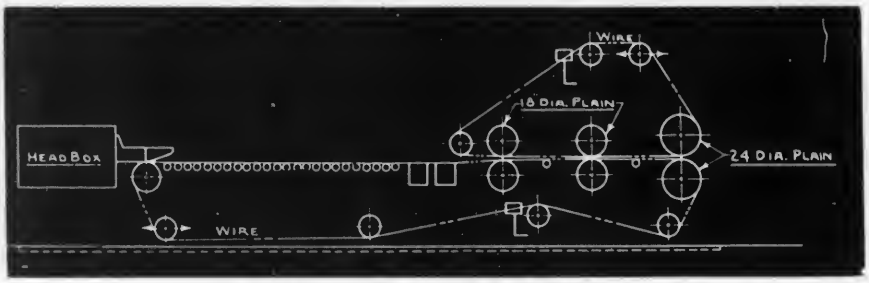


Fig. 6.—Elevation of 64-inch hardboard machine.

is a multi-deck rack with the number of openings corresponding to the number of openings in the platen press. In the wet process this is usually a 20-opening affair.

By one method of loading the cut boards move automatically into the various decks of a stationary rack by means of a tipple arrangement. When this rack is loaded the boards are moved simultaneously into a movable intermediate rack which has been connected to the stationary rack. This movable rack after being filled is moved to the press and the boards transferred in one operation into the press.

By another method of loading the rack being loaded from the machine is elevated a deck at a time until it is filled. The boards are then moved simultaneously into the open press.

Because it is consolidated while it is wet, wet process board requires a screen on one side of it so that in drying the steam generated may escape. This leaves a permanent wire mark on one side of the board. Stock prepared for wet process board is free enough to permit this escape of steam during pressing. Thus it is unnecessary to refine the fibers to the degree required for insulating board.

Dry Process Hardboard

Stock for hardboard by the dry process may be prepared somewhat similarly to that prepared for wet process board. The fibrous mat is formed and pressed in the same manner as by the wet process. However, unlike the wet process the board for the dry process is passed through a long drier and dried to bone dryness or nearly so before it is placed in the platen press for consolidation into hardboard. The product before pressing is similar in appearance to insulation board. Pressures for dry process board are usually higher than for wet process board (1,000 to 1,500 psi.) as are the temperatures, 300° to 450° F. The pressing cycle is considerably less as it is possible to consolidate the board in as small a time interval as 1½ minutes. Usual pressing cycles are 2½ to 3 minutes.

Dry process hardboard is smooth on both sides as both of the press platens or caul plates used are smooth. Fiber prepared for dry process board is usually refined to a higher degree than for wet process board to allow for easier handling of the unconsolidated board. The quality of the pressed board depends on the quality of the unpressed board.

The amount of unreclaimable trim from board made by the dry process is about 3 percent less than for the wet process.

While dry process board requires a drier for making the board, because of the shorter press-

ing cycle a press with fewer openings is required than is used for the wet process. Loading and unloading equipment also is usually not as complicated or costly.

Humidifier

In addition to equipment previously described it is essential in hardboard manufacture to provide a chamber wherein the board which is bone dry after pressing may be humidified to a moisture content of 5 to 6 percent before being packaged. Unless this is done the dry board tends to warp unevenly as it picks up moisture from the air.

There is no standard method for humidifying the board. One method consists of unloading the boards from the press into buggies where they are placed on end with spacers between. Each buggy should contain a multiple of the number of openings in the press. The humidifier consists of a tunnel with tracks to guide the buggies full of board. To prevent the humidifier from being excessively long the tunnel may be wide enough to accommodate, for example, two or three pairs of tracks in parallel. It is convenient to have some sort of puller mechanism so that the full line of buggies can be moved forward one buggy at a time as they are periodically loaded from one end and unloaded from the other.

One company has an open tunnel with rollers along the bottom and wire spacers running lengthwise of the tunnel about 30 inches above the rollers. Boards are loaded on edge on the rollers two boards to a space. The rollers carry the board along slowly and they are unloaded by hand at the far end. Both ends of the humidifier are open and air is circulated upwards and downwards between the boards. The air is humidified in equipment either on top of the humidifier or beneath the floor.

Obviously a continuous roller deck humidifier would be ideal. However, with humidification running from 4 to 6 hours this would be a rather lengthy and expensive piece of equipment. For a very large production though a humidifier of this type might be feasible. Boards could be fed directly from the press into the humidifier with only a transfer in between.

In the normal humidifier the relative humidity is on the order of 80 to 85 percent. The higher the temperature the more rapid is the rate of humidification. However, temperatures too high present operating problems not encountered in the lower range. It has been found practical to humidify at temperatures of 100° to 120° F.

Heat Treating

Heat treating of hardboard has been found practical to increase strength. The method heat treating may be similar to that for humidifying except that moisture is absent. Temperatures of 120° to 140° C. for 4 hours has been found to increase the strength of wet process board about 25 to 30 percent.

Tempering

For some uses it has been found advisable to "temper" the hardboard. This tempering is accomplished by adding a resin or oils such as linseed, tung, soy bean or tallol. This additive may be combined with the pulp in the form of an emulsion or the boards may be dipped into tanks containing it. The impregnated board is heat treated in hot air chambers and care must be exercised due to the fire hazard.

Combination Plant

It may be advisable in some locations due to the available market to consider a plant in which it is possible to make both softboard and hardboard. Thus when the demand is low for hardboard, the plant can be used for making softboard or vice versa. One such combination plant is shown in Fig. 7.

As in the manufacture of soft or insulation board it is necessary to use a drier, such a plant is equipped to manufacture hardboard by the dry process. Investment in a combination plant is, of course, not too much higher than for a plant equipped to make either the hard or soft product.

Plant and Process Considerations

In planning any type of mill for the manufacture of board there are a number of important considerations.

The available and future market is, of course, the prime consideration in planning for a mill. It is of no avail to make a good product unless it can be sold. The number of uses for both soft and hardboard is being materially in-

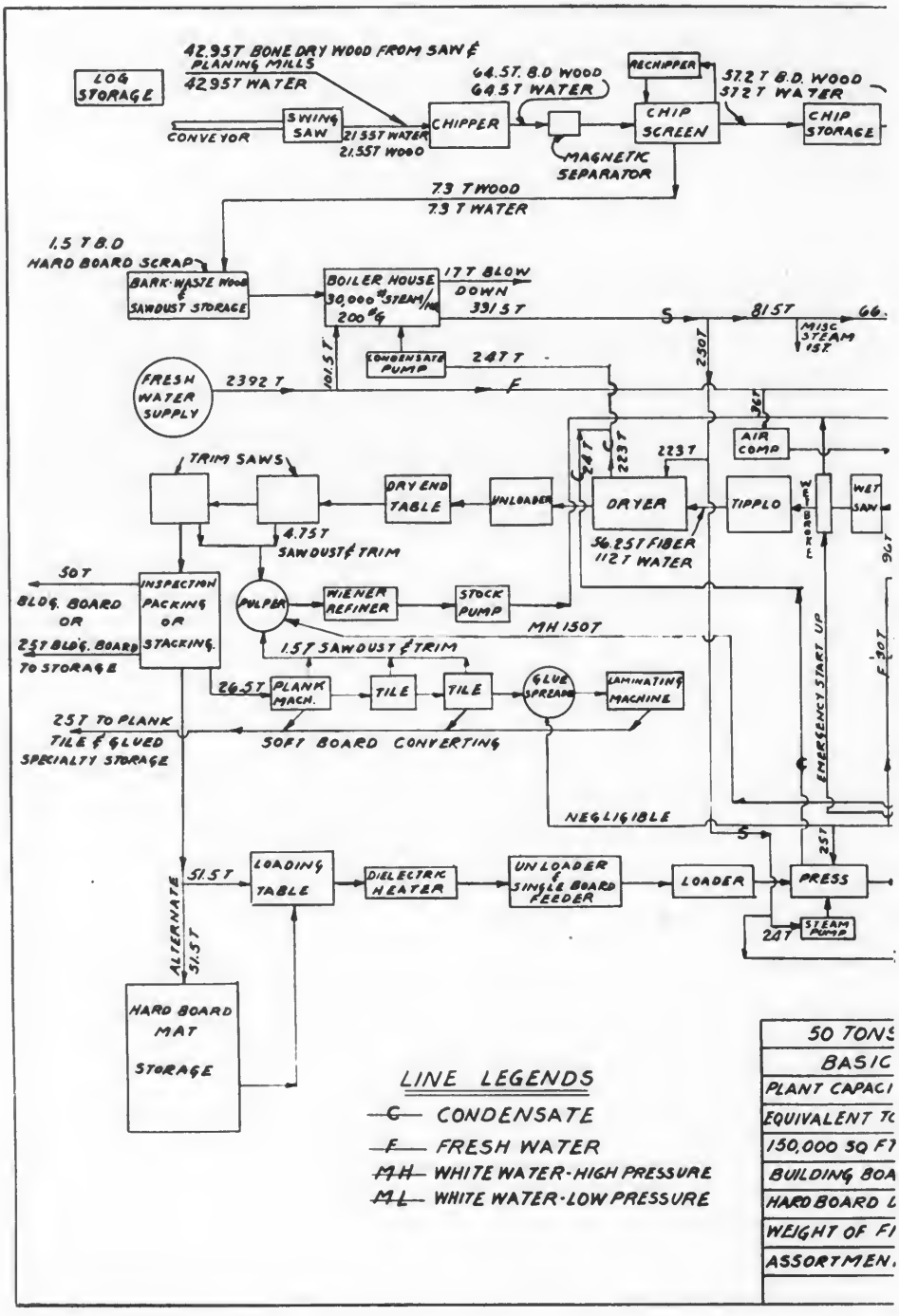
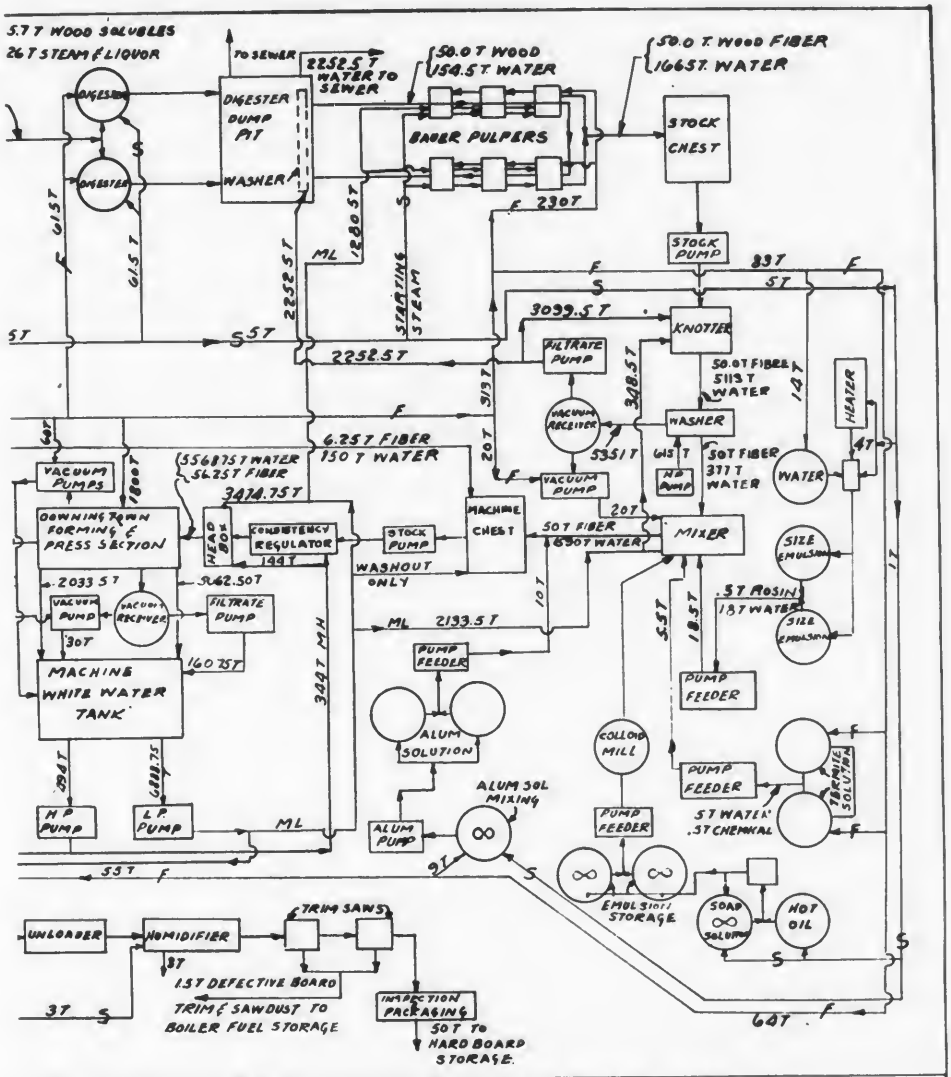


Fig. 7.—Flow diagram of combi-



5 OR 150,000 SQ.FT PER DAY COOKED WOOD FIBER BOARD PLANT

DATA	RAW MATERIALS	EFFLUENT
TY-50 TONS (2000 LB)	GREEN WOOD-431 TON IN 24 HRS	DIGESTER LIQUOR & VAPOR-26 T IN 24 HRS
) APPROXIMATELY	SAWMILL WASTE 42.95 T B.D 24 HRS	WATER FROM WASHER 2252.5 T IN 24 HRS
: OF ½" THKK	MOISTURE CONTENT (GREEN WOOD)-50%	EVAPORATED IN DRYER 112 T IN 24 HRS
RD OR ⅛" THICK	ROSIN SIZE (SOLIDS). 5 T IN 24 HRS.	MISC. STEAM 15 T. IN 24 HRS.
EPENDING ON THE	ALUM OR EQUIVALENT 1.0 T IN 24 HRS.	BOILER BLOWDOWN 17 T IN 24 HRS.
NISHED BOARD &	TERMITE CHEMICAL .5 T IN 24 HRS.	
R OF PRODUCTS.	FRESH PROCESS WATER · APPROX.	
	2400 TONS OR 400 G.P.M.	

nation hardboard-softboard plant.

creased and we may expect them to continue to increase as the methods for treating and converting improve. A better product and lower cost of manufacture will also permit these products to compete with existing products used for similar purposes.

Type and Continuity of Raw Material

The available raw material is a major consideration in selecting stock preparation equipment for making board. Also, it must be certain that the mill once established will not soon lack for easily available raw material within the price range which will enable it to make and sell board competitively. The amount of this raw material will also be of major importance in deciding the size of mill to be built.

Cost Consideration

Available capital, of course, will determine to a large extent the size and type of board plant to be built. Some types of plants will require a heavier investment than others. This initial outlay, however, should be balanced against the overall cost of making board after the plant is built.

Power supply should be ample and power rates should be low enough to permit this portion of board cost to be in balance. Cost of power is also important in determining the type of equipment to be used.

Cost of labor is a large percentage of the expense of manufacturing board. Processes should be planned to operate with a minimum of labor. This labor cost will set to a large extent the size of mill as labor costs for low tonnage mills are usually higher than for the higher tonnage plants. Maintenance of equipment is a large factor in computing labor costs.

Other Factors

Availability and type of labor, distance to markets and other minor considerations should be given careful study before a plant is built for making board. As in other paper mill type operations the plant once established should prove to be a permanent one if the present growth rate of soft and hardboard usage is a satisfactory criterion.

Discussion

Mr. E. D. Marshall (Texas A & M College): I realize that it is difficult to qualify the word "small" in your paper on small plant set-up for insulation and hardboard manufacture. However, under existing economic conditions, what is your estimate of a minimum investment to set up a small plant for insulation board and hardboard?

Mr. DePan: It depends on the size and elaborateness of the process and equipment contemplated to be able to quote on plant investment. It will vary considerably.

Mr. A. Elmendorf (Elmendorf Research Inc.): What is the average life of screen on the hardboard machine?

Mr. DePan: The life depends on the angle of rolls or return angle of the wire plus drag on the suction boxes. A good average is six months for the top wire; and two to three months for the bottom wire.

Mr. C. C. Heritage (Weyerhaeuser Timber Company): Will you elaborate on the benefits of suction presses versus plain presses?

Mr. DePan: You get a better board with suction press, less possibility of board distortion and more versatility of operation.

Mr. L. A. Mueller (Northern Rocky Mountain Range and Experiment Station): I would like to hear Mr. DePan discuss what he feels would be approximately the minimum size plant he considers economic in terms of square footage of output.

Mr. DePan: This depends on operating costs and the type of market in which the board competes. A rough estimate for normal hardboard would be a minimum of 50,000 square feet per day.

FOREST PRODUCTS RESEARCH SOCIETY

Manufacture of Consolidated Products From Wood Residues

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With the use of modern synthetic-resin binders and through the exercise of proper process controls, wood residues such as planer shavings can be consolidated into board products, molded shapes, die-pressed materials, and other useful items. The purpose of this report is to provide information that may prove helpful to persons or organizations who wish to utilize wood residues as raw material in the manufacture of such products. Information and data that are presented are, by virtue of the scope of the problem, limited in nature. Only one type of wood residue in combination with one type of resin binder is considered in detail. It may be assumed, however, that the experiences and techniques reported herein will apply also to processes and materials that are similar, though not identical in nature with those examined.

A VARIETY of end products can be manufactured from wood residues if the recommendations in this report are followed. Flat board materials, molded shapes, die-pressed shapes, and laminated products (using resin-bound wood particles as a core) can be fabricated so as to encompass a wide range of density, strength, water resistance, shape, and appearance. Not all of the foregoing possibilities are described in detail, but sufficient information is provided to enable intelligent consideration of those factors that might be involved in the manufacture of any one of the items.

Wood as a Raw Material

Requirements for fabricating a board product by means of a dry process technique, using a thermosetting-resin binder, are such that the nature of the wood particles used is not critical. The product described in this report is a dry-process board and, in view of the foregoing, planing mills and wood fabricating plants may be regarded as satisfactory sources of wood raw material. Consideration must be given, however, to the fact that before a supply of suitable wood particles can be manufactured into uniform resin-bound board products, it must have, regardless of source, a constant moisture content and must be composed of particles that are consistent in range of size.

Moisture content should be controlled at about 4 percent. This can be accomplished through the use of standard drying equipment. Devices that are suitable for drying shavings and similar materials are available and are capable of drying these materials to any desired value from an initial moisture content that may be above the fiber-saturation point. It is not too difficult to dry materials of this type since the amount of surface area exposed to the controlled drying atmosphere is large in relation to the total volume of each piece. A higher or lower moisture content value might be as satisfactory as the prescribed optimum of 4 percent, provided it is held constant, and provided correction is made, during the operation of resin coating, for the amount of moisture in the wood particles. Factors which determine the amount of moisture that can be tolerated in a mat are associated largely with the operation of hot-pressing; these will be described more fully in subsequent discussion.

Wood particles, unlike wood fibers, have little if any ability to hold together mechanically when consolidated into a mat. As a result, the physical strength of a board made from wood particles is dependent on the quality of surface bond that exists between individual particles. An exception to this is the fact that a small amount of mechanical strength is imparted to boards made from fibrous particles, such as the long curled shavings produced by some types of stickers and planers.

Since strength is dependent on adhesion of particles, it is important to apply binder resins so that they provide maximum surface coverage. The ultimate objective should be to cover the entire surface area of each particle with an optimum amount of binder, so that satisfactory physical characteristics can be developed in the end product. Thin coatings of resin provide a

bond that in most cases has less strength than wood material itself. Heavy coatings are wasteful because of the fact that the strength of a bond is not improved by the presence of thick films. Also, excessive resin binder will tend to be absorbed by the wood particles. This excessive resin does not contribute properties that are commensurate with the additional cost. The amount of binder required to provide an optimum coverage is influenced by the size of the particles. A given quantity, by weight, of large wood particles has considerably less aggregate surface area to be covered with resin than a comparable quantity of small particles.

Considerable leeway is possible in determining an optimum size range of particles. Materials like sawdust have the disadvantage of possessing large surface areas per unit volume, thus requiring excessive quantities of resin in order to establish desirable strength values. Very large particles introduce problems of resistance to densification under pressure. It is also difficult to coat their entire surface area with binder. Exploratory investigation has given indication that moderate particle sizes are most satisfactory. An exact range has not been established, but an acceptable classification should include material that will have a minimum mesh size of 0.05 inch and a maximum mesh size of 0.25 inch.

Resin Binders

Physical characteristics of resin-bound materials are derived from the quantity and quality of binder that is used in their manufacture. The quantity of resin binder used is expressed as a percentage of the total weight of the final product. In most cases, this value is determined on the basis of solids content of the resin under consideration.

A study of the effect of variation of resin content constituted one of the major experimental activities incident to this report. It was found that a board of acceptable quality could be made with a resin content of about 2.5 percent. Progressive depreciation of strength, water resistance, and other physical characteristics took place as resin content was decreased to 2.0 percent and lower. Improvement of physical qualities was realized when resin percentages were increased above 2.5 percent. Improvement tapered off rapidly as higher resin percentages, in the vicinity of 6 percent and greater, were used.

With the range in particle size used in this experimental work, a resin content of 2.5 percent appeared to give a complete surface coating of each individual particle with resin. Therefore, virtually no voids or areas without interfacial bonding of contacting particles existed in the finished product. At binder values of less than 2.5 percent, voids did exist; strength was reduced and transfer of moisture was facilitated between particles. As resin percentages were increased above 2.5 percent, each particle received a thicker coating of binder, which resulted in improved adhesion between particles and was manifested in an improved board product. As resin content was further increased, the maximum strength of the resin itself was approached, with the result that improvement tapered off.

Satisfactory application of low percentages of liquid resin mixtures to dry wood particles cannot be accomplished by means of mechanical mixing. High resin concentrations are usually produced at the point of introduction of the resin to the mix, while succeedingly smaller amounts of resin in the material surrounding the areas of high concentration serve to contribute to a lack of uniform distribution. The hygroscopic nature of dry wood aggravates this situation by absorbing moisture from the resin mixture, thereby retarding resin diffusion to all wood particles. Also, wood particles in the region of high resin concentration become thoroughly impregnated with resin, which is not necessary or desirable from the standpoint of obtaining maximum physical properties in the end product.

At the outset of this investigation, it became necessary to develop a means of coating particles in such a manner as to avoid the shortcomings of mechanical mixing. An apparatus based on the principle of spray coating particles as they are suspended in air was ultimately developed to fill the need. Details of this apparatus are described in the discussion of equipment.

A technique of spray coating was developed that permitted independent control of both moisture application and resin application. Because of this feature, it was possible to process material, within the physical limits of the ap-

paratus, to any value of moisture content and resin content that might be specified. The use of water-soluble phenol formaldehyde resin was necessary in order to provide this control. Various mixtures of resin and water, on a volume basis, ranging from 1 part of water with 2 parts of liquid resin, to as much as 4 parts of water and 1 part of liquid resin, were used, depending on the moisture content and resin content desired for the coated particles.

Pressing

Attainment of desired physical characteristics in a product made by consolidating mixtures of resin and wood particles is as dependent on the technique and condition of pressing as it is on the nature of the raw materials themselves. In virtually all cases where synthetic resins are used as binders, pressing at elevated temperatures and pressures is mandatory. The technique of pressing, in most cases, amounts to establishing a proper correlation of time, temperature, and pressure with the type of resin binder, type of wood particle, amount of free moisture present, and the desired end result.

Time and temperature requirements are interrelated to the extent that resin binders require specific amounts of heat for given periods of time in order to attain a degree of condensation (cure) that results in a permanent bond. Heat has a catalytic effect on the rate of condensation of all thermosetting resins. Therefore, to realize cure throughout the thickness of a consolidated product, it is necessary to reach a predetermined degree of temperature throughout the layup. The recommended temperature for most synthetic resins is around 250° F. at the midthickness of the material being pressed. The time required to reach the desired midthickness temperature establishes the press cycle time.

The amount of pressure that must be applied to a layup during hot pressing is determined by the qualities of strength, density, and appearance required in a finished product. Generally speaking, low-pressure applications result in low density, moderate to poor strength, and poor moisture resistance. These characteristics may be altered to a considerable extent, however, by the type and amount of binder that is used. Application of high pressures results in improved physical qualities. A range of pressure up to 200 pounds per square inch may be considered low for the production of a hardboard material. Pressures ranging from 200 to 600 pounds per square inch are desirable for most particle board products. Die-pressed materials have been made from wood particles with pressure applications reaching 5,000 pounds per square inch.

Flat board products that were tested and evaluated comparatively during the conduct of this investigation were pressed at standard conditions of 300° F., and 300 pounds per square inch, for 10 minutes. Boards were cold flushed at the end of the press cycle as a means of avoiding surface blisters. Cold flushing amounted to running cold water through the steam platens until they had cooled to a point below 212° F.

The problem of cold matting resin-coated particles was investigated in considerable detail. Unlike wet-process fiber mats, dry-process wood material has little if any tendency to hold together prior to the application of external pressures. It was found that by adjusting the moisture content of particles comprising a mat to a value of between 10 and 35 percent of the weight of dry shavings, preferably between 18 and 27 percent, it is possible to prepress the mat cold, using relatively simple equipment, until it is consolidated sufficiently to be self-sustaining, that is it can be handled. A prepressed mat produced in this manner, through accurate control of moisture content values, may be handled by ordinary methods and equipment when cutting it into suitable lengths, transporting it from the felter to the hot press, and introducing it into the latter.

The effect of adjusting moisture content values of the mat on its ability to be cold pressed to a self-sustaining condition is illustrated by the data presented in Table 1. These data constitute the results of tests conducted by spray coating representative particles with 2.5 percent binder content, yet varying the total moisture content as indicated. The particles were formed into mats, which were faced with resin-impregnated (plastic) paper, then prepressed cold over the indicated range of pressures. Self-sustaining qualities of the prepressed mats were observed, the mats being described

TABLE 1.—RELATIONSHIP BETWEEN MOISTURE CONTENT, PRESSURE, AND SELF-SUSTAINING QUALITIES OF MATS FACED WITH RESIN-IMPREGNATED PAPER

Example No.	Moisture content[1] of unpressed mat Percent	Self-sustaining quality at cold prepressing pressure[2] of					
		50 psi.	100 psi.	150 psi.	200 psi.	250 psi.	300 psi.
1	11	—	—	—	—	+	+
2	15	—	—	+	+	+	+
3	19	—	—	+	+	+	+
4	23	—	+	+	+	+	+
5	27	+	+	+	+	+	+

[1] On oven-dry basis.
[2] +, felt self-sustaining; —, felt not self sustaining.

as self-sustaining if they held together sufficiently to permit cutting into unit lengths and introduction into a hot press.

Felting of resin-coated particles can be accomplished in a satisfactory manner if a continuous technique, as described under *Spray Coating Apparatus,* is used. Mechanical mixing methods, on the contrary, usually make felting difficult. Regardless of technique, effort should be exerted to produce a mat of uniform density and thickness. Failure to achieve this will result in serious consequences following final hot pressing. A product having nonuniform density, which in most cases results from poor felting, may have extreme variations in physical characteristics and, in all probability, it will warp considerably.

The density of a consolidated board is dependent on the amount of pressure applied. Other factors, such as density of the particular wood species used, temperature at time of pressing, and specific gravity of the resin binder, also have an effect on the final product.

Faces

Although unfaced consolidated board products are attractive and possess satisfactory physical qualities, the addition of faces to both surfaces generally results in an improved product. Excellent results have been obtained with resin-impregnated paper, kraft paper, sliced veneer, rotary-cut veneer, and cloth. It is probable that satisfactory results could be obtained with sheet plastics and thin metals, provided adequate surface-bonding adhesives are used. The fact that these materials can be applied as faces at the same time that the core material is being consolidated under heat and pressure is of particular advantage from the standpoint of facilitating production.

Data presented in this report are derived largely from board products that were faced with grade 3000 "Kimpreg" resin-impregnated paper. Faced boards were studied because they have more practical industrial applications than unfaced boards. Facings improved appearance, workability, and strength.

Sliced and rotary-cut veneers make extremely attractive faces for consolidated cores. It is possible to produce a minimum-cost product faced with mahogany, walnut, or other decorative veneers. These products, when made in the desired thickness, may be used wherever hardwood plywood or lumber core stock is currently being used. It is mandatory to use a balanced construction when veneers are used for facing. Although it is preferable to use a two-ply face, with the grain of adjacent veneers oriented at right angles, a single ply can be used.

Face materials must be coated with adhesive on the surface adjacent to the core. At low resin contents there is not a sufficient quantity of free binder in the core to provide adequate bonding of uncoated face material. Experimental results indicate that a sprayed coating of about 2.5 pounds of resin solids per 1000 square feet of veneer will provide adequate bonding between core and face when the core resin content ranges from 2.5 percent upwards. Adequate bonding of paper can be obtained with about the same resin application as that specified for veneer. Cloth, on the other hand, requires a considerably greater spread in order to provide sufficient resin to fill the interstices of the material. This requirement will vary with different types of cloth.

Steam accumulation between faces and core composites presents a problem during hot pressing. It has been found that resin-impregnated papers and similar impervious face materials are more susceptible to this condition than veneers, fabrics, and other materials that allow steam accumulations to dissipate by diffusion. To overcome the difficulties associated with this

condition, heated platens should be cooled to a point well below 212° F. before hydraulic pressure is released from the assembly. Steam pockets are more likely when platen pressures are increased. Experimentation is the only way in which to determine the actual need of cold flushing. With certain face materials, the rate of escape of steam from the assembly may be sufficient to obviate its need.

Die-Shaped Products

With the use of properly constructed dies, resin-coated wood particles can be formed into shapes of simple or compound curvatures. Products, such as wheels for toy automobiles, blank shapes for toys, coasters for glasses, and knife handles, can be formed in plunger-type dies. Other products designed to conform to simple curvatures, such as packing carton separators, waterfall shapes for furniture, kitchen cabinet ends, molded baseboards for home construction, cove molding, and clock cases, can be readily made either with or without face materials.

To determine the feasibility of making such products, an experimental die was constructed to produce coasters for glasses. It was found that particles of the previously described standard mesh size, when coated with 5 percent binder and pressed at 5,000 pounds per square inch at 300° F., produced a product that had high strength and excellent water resistance. The wood particles used in this investigation were coated in such a manner as to add a minimum amount of moisture. This was done in order to avoid formation of high-pressure steam pockets that would doubtless be associated with the high pressures that were applied. It is not essential to use pressures as high as those used in this instance, but for small unit-sized items a high pressure may be desirable from the standpoint of appearance of the finished item. Some coasters were faced with printed rayon cloth, the results being quite satisfactory from the standpoint of appearance.

Plunger-type dies should be constructed with sufficient clearances to permit the escape of water vapor as it diffuses from the material being pressed. It may be desirable to provide a cold plunger die of rough dimensions for instantaneous application of pressure to form mats (or blanks) to be fed into a more accurately made heated die. In lieu of provision for cold matting, sufficient plunger travel should be allowed in the hot die to permit at least a 16–to–1 ratio for compressing loose material into a consolidated state. This same compression ratio must be allowed for in a cold matting die. Variation of particle size can affect this ratio to a considerable extent.

Products molded to simple curvatures and faced with veneer or other face materials can be produced with relative ease and economy. Experimental molded units were made ¼ inch in thickness, with a 90° bend on a 2-inch radius. Various units were faced with Kimpreg grade 3000 resin-impregnated paper, sliced mahogany veneer, sliced walnut veneer, kraft paper, and left unfaced, all with fully satisfactory results.

Development of pressing technique enabled the use of fixed-center dies of standard design, a type generally used in the manufacture of molded plywood. Layups of desired size were prepressed in a manner identical with that recommended for the production of flat board products. Self-sustaining cold-pressed mats were then inserted between the opposed elements of the die. Spring brass cauls were used on both surfaces to provide retention, thereby avoiding possibility of mat disintegration during the period of die closure. If veneers or other rigid face materials are incorporated in a layup, the use of metal cauls is not necessary.

Physical Properties

Appearance

Unfaced products have a unique, attractive surface appearance that might be considered desirable for certain decorative or architectural applications. The characteristics of the surface are affected by the amount of resin binder used and by conditions of pressing. Incorporation of high percentages of phenolic binder (roughly 5 per cent or greater) results in a decided darkening effect on the color of the wood particles; it also produces a surface glaze that may be desirable in some instances. The effect of pressure is manifested in compactness or hardness of the product. The size of wood particles used contributes to appearance. Small particles produce a homogeneous-appearing product, while large particles retain their individual identity, thereby producing an attractive design.

Modulus of Rupture

Fig. 1 shows the range of modulus of rupture values for various percentages of binder content. The values were obtained by testing ¼-inch thick specimens in conformity with the procedure outlined in Federal Specification LLI–F–311, Fiberboard, Hard. Test specimens were cut from boards that were originally 12

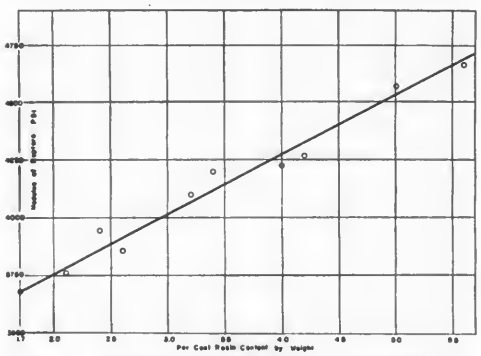

Fig. 1.—Modulus of rupture of spray-coated ¼-inch wood residue board faced with a plastic paper and bonded with phenol formaldehyde resin.

inches square. Conditions of pressing were identical for all specimens: 300 pounds per square inch at 300° F. for 10 minutes, followed by cold flushing as explained in previous discussion.

Modulus of rupture values drop sharply with resin binder contents lower than 2 percent. As resin content is increased above 2 percent, strength values tend to improve proportionately. At approximately 6 percent, improvement in strength tends to taper off. This is attributed to the fact that the maximum strength of the binder resin begins to affect the modulus of rupture near this point.

The values used to plot the curve in Fig. 1 were obtained by testing boards faced two sides with Kimpreg grade 3000 resin-impregnated paper. It was determined that unfaced boards processed in an identical manner and of the same thickness had strength values approximately 20 percent lower than those shown.

A correlation exists between strength and moisture content at time of pressing. From the standpoint of obtaining maximum strength, total moisture content should be held in the vicinity of 25 percent. As moisture content decreases, the modulus of rupture decreases; roughly, a 20 percent decrease in value of modulus of rupture can be expected when the moisture content is at or below 12 percent.

Since resin binders are costly, it is desirable to determine a point at which the economics of product manufacture can be balanced against use requirements. This investigation has led to the conclusion that a resin content in the range of 2.5 to 3.0 percent should be considered as an optimum. It is true that improved strength can be obtained with higher resin contents, but the improvement is in no way consistent with the increased costs of manufacture that would be incurred. Certain specialty items that bring a high market price may warrant the addition of more binder material.

Water Absorption: 24-Hour Immersion

Specimens obtained from boards of identical characteristics as those used in determining modulus of rupture values were exposed to a 24-hour immersion in water, at 72° F. Moisture absorption by specimens having various percentages of resin binder content is shown in Fig. 2. Percentage increase in board thickness and percentage increase in board weight are illustrated. A resin-impregnated face material did not materially affect the rate of water absorption. Unfaced materials can be expected to react a little less favorably to the same exposure.

It should be noted that at resin content values of less than 2 percent, the rate of absorption rises sharply. Little if any improvement in moisture resistance is provided by resin content values in excess of 3.5 percent.

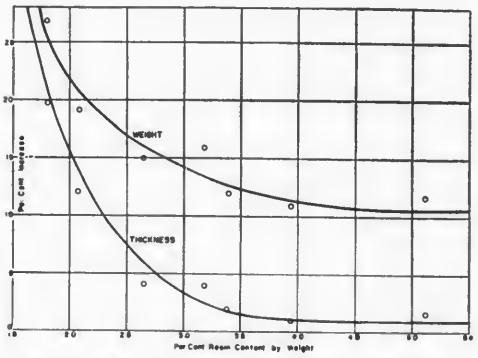

Fig. 2.—Water absorption after 24-hour soak of spray-coated wood residue board ¼ inch thick, faced with plastic paper and bonded with phenol formaldehyde resin.

Water Absorption: 10-Cycle, 24-Hour Exposure

Fig. 3 shows the effect of alternate 24-hour immersion in water followed by drying in a 12 percent equilibrium atmosphere at room temperature for a total of 10 complete cycles. Specimens that were subjected to this test were taken from the same boards used to provide samples for the 24-hour immersion test.

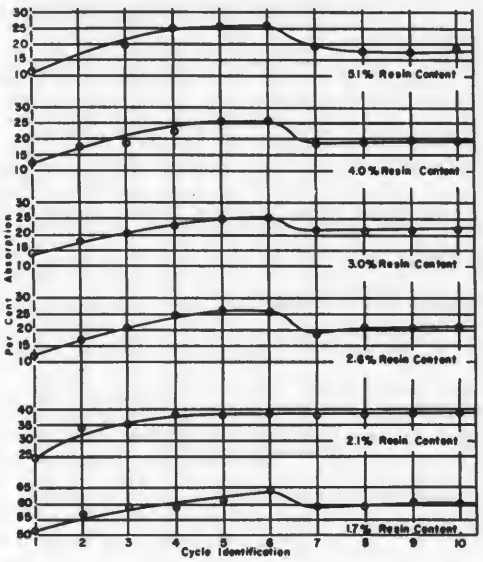

Fig. 3.—Water absorption of wood residue board in 24-hour cyclic test (alternate wet and dry exposure).

Values shown indicate the percentages of moisture absorption at the end of each period of immersion in water. The effect of resin-binder content on the amount of water absorption is readily discernible from the graphs.

The decrease in moisture absorption percentage in evidence between the sixth and seventh cycles is attributed to the fact that a 48-hour drying period was inadvertently allowed in that one instance. For some reason, the excessive drying period resulted in a loss of moisture that was not picked up again during the remainder of the test run.

Visual inspection revealed that samples were in fair to excellent condition at the termination of testing. Samples with a resin-binder content of 2.1 percent or more showed little or no breakdown of structure. Those samples having 1.7 percent resin content swelled more on the edges than at the center regions of the pieces.

Equipment

The procedure of making a satisfactory product through the combination of synthetic resin binders with dry wood particles resolves into a problem of properly combining the two materials. As has been shown, the application of resin to wood particles must be accomplished in such a way that homogeneous coating of the surface of all particles is realized. At the same time, positive control of the amount of moisture that is added and the amount of resin that is applied must be maintained. Unfortunately, these requirements exceed the limitations of ordinary methods of mixing ingredients by mechanical means. It was found, however, that satisfactory coating could be achieved when separated wood particles were exposed to an atmosphere of sprayed resin binder.

Spray-Coating Apparatus

Experimentation led to the construction of an apparatus that permits controlled coating of a continuous feed of wood particles. A schematic view of this apparatus is shown in Fig. 4.

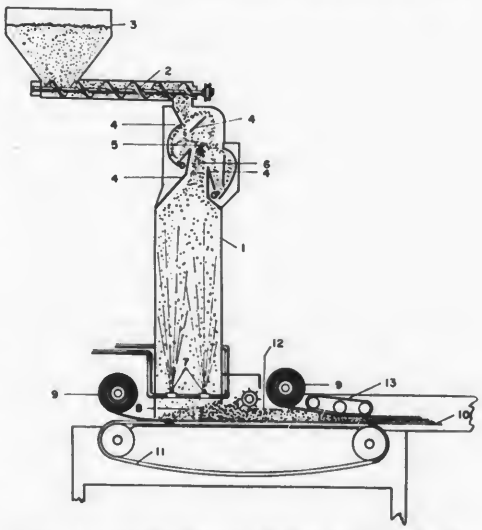

Fig. 4.—Spray-coating apparatus for coating particles of wood residue with bonding resin. 1, Coating chamber; 2, worm feed; 3, hopper; 4, baffles; 5, area of particle impingement; 6, throat of coating chamber; 7, spray nozzles; 8, chamber pass-out; 9, mat-feed rolls; 10, matt assembly; 11, conveyor; 12, mat; 13, metal belt for prepressing.

It comprises a coating chamber (1) of suitable dimensions, which may be fabricated from either wood or metal. The upper end is provided with means for introducing a controlled and measured feed of the wood material to be coated with binder and then felted into a mat and consolidated. The introducing means is a variable-speed worm feed (2) that is supplied with material from a suitable hopper arrangement (3).

Planing-mill shavings or other refined wood residues introduced into the chamber by the worm feed tend to cling together and form aggregates or loose clusters that cannot be effectively coated with a liquid binder material; hence, means are provided for disintegrating these particle masses. The separated particles are entrained in a gaseous stream and subsequently coated with liquid binder. The disintegrating and entraining are accomplished by several jets that supply air at high velocity to the upper portion of the chamber. The streams of air from the jets are directed against the material as it feeds into the chamber, striking it with sufficient force to separate the component particles.

A series of baffles (4) is strategically positioned so that the entrained particles are divided into opposed streams that impinge on one another in region (5). The impinging action results in an area of high particle density and low velocity directly over the throat (6) of the coating chamber. At this point the particles fall at low velocity into the coating chamber, where they diffuse evenly over the cross-sectional area and are exposed to a controlled atmosphere of atomized resin.

The resin mixture is introduced into the coating chamber in a direction counter-current to the stream of falling particles. Atomizing spray nozzles (7) placed near the bottom of the chamber discharge an appropriate combination of compressed air and pressurized resin-water mixture. Control of the amount of resin that is atomized is obtained by adjustment of air and mixture pressures. The ratio of resin to water in the atmosphere of atomized binder, the factor that determines final moisture content of the coated particles, is adjusted by diluting the neat resin.

The rate of feed of wood particles through the apparatus, when coordinated with the amount of resin being atomized within the coating chamber, determines the final resin content of the coated material. Careful adjustment of these two variables is necessary to avoid either partial coating of particles or a condition of excessive coating accompanied by superfluous resin deposited on the chamber walls.

After being coated with binder, the particles pass out the bottom of the chamber (8) which is open to the atmosphere and positioned above an endless conveyor (11). Coated particles deposited on the conveyor are passed beneath a picker roll, thereby forming a mat of density and dimensions suitable for consolidation.

Face materials may be introduced under the discharge end of the coating chamber by means of the endless conveyor belt. Paper or cloth facing that has been coated with a suitable adhesive on the side that is to be in contact with the deposited mat may be fed from rolls (9) as indicated. Other means may be devised for feeding veneer and similar face materials that cannot be handled as conveniently as paper. After a mat (12) has been deposited on the bottom face, a top face may be applied to complete the assembly. Following the introduction of both faces, the assembly (10) can be prepressed in accordance with the recommendations of Table 1, by means of a traveling metal belt (13) or some other device.

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Discussion

Col. W. B. Greeley (West Coast Lumbermen's Assoc.): Can you provide an approximate cost of a plant installation?

Mr. Macdonald: A rough estimate for a small plant would be $50,000 to $75,000.

Mr. H. J. Knapp (Fred G. Greaves Company): What types of mechanical mixing equipment have you tested?

Mr. Macdonald: Our mechanical mixing was done with a rotary beater. Equipment limitation prevented us from experimenting with other types of mechanical mixing equipment.

Mr. Knapp: Have you operated a full width spray tower suitable for producing a 4-foot wide panel?

Mr. Macdonald: No, only experimental equipment (1 foot in width) has been operated—full scale equipment is rarely used in laboratory work.

Mr. Knapp: Have you experienced build up of resin on tower baffles during 24 hour continuous operation?

Mr. Macdonald: We have had little trouble with accumulation of excess resins. Resin does not get up into baffle section. Accurate correlation of resin mixture input with rate of feed of wood particles eliminates superfluous resin that might otherwise be free to accumulate.

Mr. E. E. Harris (Forest Products Laboratory): Have you tried urea resins for the consolidated products? Are other resins less satisfactory than phenolic resins? What improvement do you get with increased resin?

Mr. Macdonald: We have tried ureas. We think they are comparable to phenolics, but not as adaptable to spray coating. Increased resin up to 10 per cent improves strength and water absorption characteristics.

Mr. T. R. Miles (Consultant, Beaverton, Ore.): What are the dimensional stability characteristics as compared to competitive materials such as plywood, fiberboard, etc.?

Mr. Macdonald: Very comparable. A board with 2.5 per cent resin content and ¼ inch thick at .9 specific gravity will increase 8 per cent in thickness during a 24-hour soak.

Mr. F. Hughes (Fred Hughes Laboratory): Were the top sheets of special nature? What was the resin content?

Mr. Macdonald: Top sheets were of "Kimpreg"—a resin impregnated paper. Since this is a trade named product, specifications as to resin content are not known. A small per cent of binder resin is added directly to surfaces in order to bond veneers to a residue core. Roughly, 2.5 pounds of resin solids per 1,000 square feet of space material are required for adequate bonding.

Dr. J. d'A. Clark (Longview, Washington): How do you uniformly distribute particles across the take off belt under the coating tower?

Mr. Macdonald: Use of a mechanical picker to level the deposited mat has proven successful in our laboratory trials.

Mr. C. Latimer (Nickey Brothers Inc.): Have you made boards of relatively low density suitable for furniture core stock?

Mr. Macdonald: We have, but the need for higher resin content with resulting increased cost makes the economics questionable.

Mr. H. Garland (Mich. College of Mining and Technology): Does your product exhibit any difference in properties on opposite sides due to the method of forming?

Mr. Macdonald: We have not checked this characteristic too closely. I would say, though, that any difference is of little consequence.

Mr. R. W. Miller (Simpson Logging Company): Could the consolidated products be stabilized, dimensionally, to moisture by varying the resin content or using resins other than the phenolic employed? It would seem that, given the material to be formed in a relatively finely divided and concentrated form, there would be opportunity to do this by resin treatment.

Mr. Macdonald: The dimensional stability is effected by variation of resin content. Increased resin gives greater stability. Small particles, by virtue of their greater surface area per unit volume, require higher resin content to effect a given stability or strength value. Of course, the type of resin is an important consideration.

Mr. T. E. Kelley (Washington State College): Can results be given of studies made of limits of maximum and minimum particle size?

Mr. Macdonald: These studies were incomplete. Small size particles require greater resin content, large particles offer difficulty in densifying the product. Recommended particle size is .05 inch mesh to .25 inch mesh.

Factors Influencing the Marketing of Wood Particle Board

Lester J. Carr

General Manager, L. J. Carr and Company, Sacramento, California

Since the production of dry-form wood particle board is a new art neither satisfactory quality standards nor standard tests are established. A broad and carefully studied program of advertising is essential. Pricing is dependent both on the prices of competing materials and on quality competition. Dry-form wood particle board offers large potential markets for forest products residues now unused.

Introduction

IN A presentation of this type, it is impossible for the writer to give any conclusions other than his own. At the present time, it is believed that there is no complete market survey in existence which would or could cover this subject as thoroughly as could be desired. The term "wood particle board" could cover the entire field of wallboard or industrial boards produced from wood fibre in whatever form that fibre might be. Since the writer's experience in the matter is limited to a particular type of wood particle board, the information presented herein is a result of gathering information as it applied to a particular type of wood particle board.

Quality Standards

The production of a dry-form wood particle board is still in its infancy, hence, no uniform set of standards has been adopted. As a result of this situation, each of the several manufacturers exploiting this particular field is, in a certain sense, groping. The matter of uniformity of thickness is of extreme importance in the industrial field. A definite mean and extreme on such tests as tensile strength, flexural strength, deflect and impact strength should be competently decided upon by the individual manufacturer and adopted before making any presentation of the finished material to the market. For the protection of the industry generally and to prevent an inferior product from becoming a burden to those conscientious manufacturers who are attempting to produce a reliable board, a uniform set of testing standards should be adopted industry wide as promptly as possible.

Advertising

This is one phase of marketing that should be equipped with extremely good brakes. Each of the three general phases of advertising, namely: consumer level, dealer level and jobber level, must be employed and properly timed to be effective. Also, a great deal of care must be exercised in properly setting forth the merits of the product, and over emphasis of characteristics or quality of the product should be avoided. Such over emphasis can cause trouble later by failure to live up to the advertising claim. Our own particular effort in this field embraced calling on dealers and jobbers as well as industrial users, the distribution of samples, displays at home shows and fairs, and advertising in architectural publications. It was found that the most effective coverage and results could be obtained by selecting a specific area or several specific areas and conducting a saturation market test within that area or those areas. Consumer level advertising was employed and a specific follow-up system was inaugurated. At the conclusion of a six weeks trial period definite advertising response could be measured and, of course, a definite reaction to the product could be obtained. While on this subject, it should be emphasized that the employment of a reliable agency to handle the advertising feature is the cheapest way to handle this factor.

Pricing

It is a well known fact that anything will sell at a price and this is particularly true of a new product in the market. It will be found almost without exception that regardless of what mar-

ket is approached there is in existence some product that is already serving the need, therefore, almost without exception an established price market is already in existence. In order to successfully market a new product it becomes necessary, therefore, to produce at least a minimum quality equal to that already existent in the product already on the market. With the quality factors equal, it becomes necessary to undershoot the existing market on price. If the new product contains a greater number of quality characteristics which can be successfully proven, the product can be priced at the existing market level and the additional quality factors will sell it. After the product has been successfully introduced and its quality has been proven, then the pricing factor becomes a simpler matter.

It is felt that the potential market for the wood particle board has just barely been touched and that a tremendous use will be developed for this type of product in the future in the industrial field. To arrive at a product a great deal of specialized board is, or will have to be, produced in the future. The wood particle board manufacturer would do well to insist upon the closest possible cooperation between his research department and his merchandising department for the purpose of properly exploiting this industrial field. It is felt that a number of various types of wood particle board will be engineered for particular uses and if properly approached, this field can be taken over at this time and held for years to come.

Conclusion

Considering a tree as 100 percent volume of wood, by the time it is limbed and bucked into logs roughly 62 percent of the original volume in the form of saw logs is taken to the mill. After the bark and slab operation has been performed and the sawing operation completed, approximately 52 percent of the original volume is produced in the form of usable lumber. Taking the next general step, after this rough lumber is refined to its various stages such as millwork, flooring, cabinets, furniture, etc., approximately 34 percent of the original volume finds its way to the ultimate consumer.

Some uses, such as fuel for power, etc., have been developed for the 66 percent original volume lost in the course of the various preparations, but a very considerable portion of this volume must be *converted* to an economical use.

It is felt that the wood particle board market holds the greatest potential for conversion to a profitable usable item.

It goes without saying that the greater exploitation that can be given the wood particle board or similar product the more complete utilization will then be made of the tree.

This is the proper time to urge greater cooperation among legitimate manufacturers to insure a healthy constructive growth of this industry.

Discussion

Mr. R. C. Scott: (American–Marietta Company): Is moisture absorption important or would percent swelling be more desirable from the marketing point of view?

Mr. Carr: The consumer wants to know what happens in relation to his requirement. Moisture absorption is required only from the industrial users such as refrigerator manufacturers, etc.

Mr. E. W. Wellwood (Canadian Forest Products): Canadian Forest Products, Pacific Veneer & Plywood Division has found that substantial saving in advertising costs may be facilitated if as much as possible of the advertising is done by their own staff in their own print shop rather than farming out advertising booklets to various advertising agencies.

Mr. Wellwood: Has any work been done to analyze the public reaction to a hardboard that is fire resistant and to compare its acceptance with another board that has little or no fire resistant properties?

Mr. Carr: I have done a great deal of analysis work and find that a hardboard that is fire resistant would be accepted in every instance in preference to that board which has little or no fire resistant properties.

Mr. J. F. Hamilton (Perkins Glue Co.): What advice would you give the production

phase of the industry concerning the procedure to follow market-wise before undertaking to produce a particle board?

Mr. Carr: A great deal of market research should be completed before venturing too far financially into experimental development. In most instances, specific boards can be manufactured to meet specific needs and the prospective manufacturer should determine which field he wishes to exploit.

Mr. R. W. Miller (Simpson Logging Company): The question of resistance to burning of hardboard or any wood-fiber product for that matter is well taken and it is unfortunate that it had to be dismissed without further discussion. An attempt should be made to have papers on this subject presented at future meetings since it is certain to become a factor of greater importance in the marketing of wood products.

FOREST PRODUCTS RESEARCH SOCIETY

Utilization of Douglas Fir Bark in Hardboard

Arthur B. Anderson and William J. Runckel

Oregon Lumber Company Research Laboratory, Portland, Oregon

A quality hardboard may now be produced from Douglas fir slabwood including bark. The new process can be used in a conventional wet hardboard process plant. The advantages of the bark process are (1) cheap raw material, (2) less power required for pulping, and (3) does not require chemicals to produce satisfactory moisture resistance.

Introduction

MUCH of the slabwood produced in the Douglas fir lumber mills in Washington, Oregon, California, and western Canada is used for fuel, either to supply the mill with power or sold locally for domestic use. Many of these lumber mills find that their own fuel requirements are amply fulfilled by the mill waste other than slabwood and usually there is little local domestic market for this material. Such mills have to dispose of their slabwool in wood waste burners.

In 1948 the Oregon Lumber Company began to investigate the possible utilization of its slabwood, including the bark, as a suitable raw material for hardboard. Up to this time very little information has been made available regarding the use of Douglas fir bark, or barks in general, in the production of hardboard.[1]

In the commercial production of hard- and softboards, bark-free raw material appeared mandatory. The reasons advanced for not using bark in fiberboard compositions were (1) when bark is incorporated with wood the resulting pulps are not suitable for wet lap forming machines because of the slowness of the resulting pulps, and (2) the presence of bark weakens the board below acceptable standards.

Experimental Procedure

Preparation of Bark-Wood Pulp

The mill shipped to us slabs which had been cut into 4-foot lengths. These were split into 2- to 3-inch widths and the bark was removed. The segregated bark was put through a small hammermill which had a perforated plate screen with one-inch holes. The bark so reduced was then ready to be mixed with wood chips for pulping. The bark-free wood was put through a laboratory chipper. The resulting heterogeneous chips were put through the hammermill containing the one-inch plate screen. These chips were then put on a quarter-inch-mesh screen to remove any fines and the latter discarded. The chips that remained on the screens were used in the preparation of the hardboard.

Sufficient bark-wood mixtures were weighed out in various percent compositions desired to make from 6 to 8, ¼-inch by 12-inch by 12-inch hardboards. This required from 9 to 13 lbs. of dry material for each experimental run. Warm water was added to the chip mixture prior to defiberization in an Asplund laboratory defibrator. A preheating chamber, consisting of a vertical stainless steel pipe (3 inches i.d. by 12 inches), was connected to the defibrating chamber by means of a 2½-inch stainless steel pipe with quick-opening valve. A charge equivalent to approximately 300 grams of dry material was placed in the preheater and the chamber closed by means of a screw cap. The chips were presteamed for 5 minutes (final pressure about 90 psig.) and then the defibrator motor was started and the chips were discharged into the defibrator chamber through the quick-opening valve. Steam was admitted into the defibrator chamber and the charge held for one minute, after which it was blown through a ¾-inch line into a cyclone, where the coarse fibers were collected. This procedure was repeated until all the material for a particular run was defiberized. The defiberized material was then pulped in an 8-inch Bauer laboratory disc mill, using No. 6946 plates at various plate clearances, to produce pulps of desired freeness. While the coarse fiber was being

[1] Clermont, L. P. and Schwartz, H. Studies on the Chemical Composition of Bark and Its Utilization for Structural Boards. FPRS Proceedings, 1948, pp. 130–135.

pulped, a small stream of water at 70 to 90° F. was continuously fed to the mill. Oliver freeness was determined on the stock at this stage. It is reported that the most suitable stock for commercial board-forming machines should have an Oliver freeness between 35 and 60 seconds. No difficulties were encountered in preparing bark-wood pulps with freenesses within these limits, thus eliminating one of the objections reported to be encountered when using bark in wood pulp compositions.

Preparation of Hardboard

The pulp from each run was divided into 6 to 8 parts, according to the number of quarter-inch boards to be prepared. Each pulp portion was dispersed in water (consistency about 6 percent) and transferred to a forming box (12 inches by 12 inches with facing screen of 14 by 14 mesh .025-inch wire). The pulp was stirred lightly and the water allowed to drain through a quick-opening valve, after which the valve was closed and vacuum applied to remove additional water. The wet mat was removed, placed between screens plus stainless steel cauls (13 inches by 13 inches), and put into a 42-ton-capacity hydraulic press with 12-inch by 12-inch platens at room temperature. The mat was submitted to 500 psi. for 2 minutes, resulting in a dewatered mat containing 50 percent (± 2 percent) solids. Each mat was weighed and the approximate dry weight of pulp recovery from each run was determined. A composite sample of these cold pressed mats totaling 150 grams was used for Oliver freeness determination.

Each cold-pressed mat was divided into equal parts, corresponding to the number of boards to be made from the particular test-run, to insure uniform stock for each board to be processed. Eleven hundred fifty to 1,175 grams of this pulp was weighed out, put into water to an 8- to 10-percent consistency, and thoroughly stirred with a pulp mixer for 10 minutes. If the board was to be sized the rosin size would be added at this point and stirred for 10 minutes and then an equivalent quantity of papermakers alum would be added and stirred an additional 10 minutes. The pulp mixture was then poured into the 12-inch by 12-inch forming box and water was added to about 4 to 6-percent consistency. This was carefully stirred and the water allowed to drain. When free drainage ceased vacuum was applied until the gauge indicated 5-inches of mercury or less. Then the mat was removed and a 13-inch by 13-inch stainless steel caul, which had been lubricated with silicone mold release compound (Dow No. 7), was placed on the top of the mat; a screen-caul was placed on the under side.

The prepared mat was transferred to the hot press, which had previously reached the desired platen temperature, either 375 or 410° F. The platens were electrically heated, and the temperature was controlled by an automatic thermoregulator. The platen pressure was raised to 500 psi. and maintained at this pressure for 2 minutes. The pressure was then slowly released to about 50 psi. to permit any entrapped steam, if present, to escape. This breathing cycle was maintained for 2 or 3 minutes and then the pressure was increased up to 250 or 500 psi. and the final pressure maintained for 10 to 15 minutes, depending on the cycle desired. At the end of the cycle, the pressure was dropped and the board removed for testing.

Physical Testing Methods

Oliver Freeness of Pulp Stocks

A composite sample weighing 150 grams (dry) from the cold pressed mats was thoroughly stirred in about 8 quarts of water with a mechanical pulp breaker. This was transferred to an Oliver test leaf ($\frac{1}{2}$-sq. ft. area) and additional water added up to 14 quarts of stock. The facing screen was 14 by 14 mesh .025-inch wire as used on the commercial forming machines. Vacuum was applied and when 15-inches of mercury was reached the quick-opening valve leading to the test leaf was opened and the time required to cause all free water to disappear was recorded. End of timing was the instant the surface of the pulp changed from shiny to dull. The drainage time for 14 quarts of water (less pulp) from the Oliver test leaf was 25 seconds.

Modulus of Rupture

Each 12-inch by 12-inch hardboard was edge trimmed on a table saw. A strip 3 inches wide was taken from near the center of the board, and this used to test modulus of rupture. This test was made according to Federal Specification LLL–F311, July 12, 1940.

Water Absorption and Swelling

Two 3-inch by 5-inch samples were cut from each board and used for water absorption determinations and to measure degree of swelling after water immersion. The edges of one of the duplicate samples were sealed with melted paraffin. The thickness to nearest .001-inch and weight to nearest 0.1 gram was recorded for each coupon. The samples were then soaked at room temperature for 24 hours under one inch of water. When the immersion period was completed the samples were removed from the water and placed on end for about 10 minutes to allow the free water to run off. The surfaces were then wiped with dry cloth and the samples weighed to the nearest 0.1 gram. The absorption was calculated as the gain in weight over dry weight and recorded in percent. In all data reported here, the "A" sample had sealed edges, while "B" was unsealed. The thickness was determined on the water-immersed specimen and amount of swelling calculated as increase in thickness over dry thickness and recorded in percent.

Specific Gravity

This was determined on approximately 3-inch by 5-inch samples according to the method described by the U. S. Forest Products Laboratory, Madison, Wisconsin.[2]

Experimental Bark-Wood Hardboard Runs

Effect of Percentage of Douglas Fir Bark on Board Properties

The weight percent of bark was determined on various shipments of Douglas fir slabwood (old growth) as received from the mill at Dee, Oregon, to ascertain the approximate percent composition of bark which would occur from day to day if the entire Douglas fir slabwood output was chipped and processed into hardboard. The amount of bark found on the slabwood varied from 30 to 75 percent, giving an approximate average of 45 percent bark by weight (dry basis) for all slabs examined. It is doubtful that the actual bark content would ever consistently run that high since some debarked slabs and edgings would probably be processed along with the slabs.

Since the bark is not to be separated from the slabs prior to pulping in this new process the amount of bark present from day to day would vary somewhat. Thus it was necessary to determine what effect various percentages of bark composition would have on board properties. For this purpose, four runs of bark-wood mixtures were prepared, containing 15, 25, 35, and 45 percent of bark respectively, six boards being prepared from each run. Three boards of each run were prepared without any sizing agent being added and the remaining three boards were prepared with 0.5 percent rosin size plus 0.5 percent paper makers alum (based on dry weight of board). All boards were hot pressed at 410° F., platen temperature, using a pressing cycle of 500, 50, and 500 psi; for 2, 2, and 10 minutes respectively. The properties of the resulting boards are given in Table 1 (the results cited being averages of 2 or more boards in this and subsequent tables).

It is of particular significance to note from these data that the Douglas fir bark hardboards have quite low water absorptions, even without any added sizing agent being present. And 0.5 percent size does not appear to reduce the strengths of the boards very materially. The amounts of bark used here do not materially

[2] U. S. Forest Products Laboratory. Methods of Test for Evaluating the Properties of Fiber Building Boards. Report R1712, 1948, pp. 16–17.

TABLE 1

Bark	Freeness	Pulp yield	Size	Sp. gr.	Caliper	Absorption		Swelling		Modulus of rupture
Percent	secs.	Percent			in.	Percent A	Percent B	Percent A	Percent B	psi.
15	31	90	0	1.039	.218	14.8	14.5	8.0	10.1	5,650
15	31	90	0.5	1.042	.219	8.1	11.6	7.1	9.0	5,135
25	30	90	0	1.040	.219	9.3	10.8	5.4	8.4	5,175
25	30	90	0.5	1.048	.219	7.6	9.6	4.8	7.9	5,160
35	35	87	0	1.045	.217	6.7	9.3	6.0	5.7	6,035
35	35	87	0.5	1.052	.214	5.7	8.6	5.7	8.6	4,935
45	39	80	0	1.061	.227	7.5	10.5	5.7	6.8	5,060
45	39	80	0.5	1.063	.229	8.4	9.3	5.6	5.0	5,130

affect the strength of the boards. It was noted that the color variation in the boards containing different percentages of bark was hardly perceptible.

Effect of Sizing Agents on Strength of Bark Boards

Very early in this investigation it was indicated that when normal or usual amounts of sizing agents are added to boards containing bark the strengths of the boards were reduced considerably. To indicate this characteristic of sizing agents a run was made using 35 percent Douglas fir bark, in which two boards each containing 0, 1, 2, and 3 percent rosin size followed by respective quantities of alum were prepared. The pH of all the sized pulp stocks was between 4.5 and 4.8. Platen temperature of 410° F., was used with a pressing cycle of 500, 50, and 500 psi. for 2, 2, and 10 minutes respectively. The results follow in Table 2.

TABLE 2

Size Percent	Modulus of rupture psi.
0	5,550
1	4,570
2	3,965
3	2,880

Thus, it appears evident, that the strength of bark-wood boards is lowered as the amount of sizing agent present increases. Sizing agents have similar effect on boards made from 100 percent wood fiber, as will be indicated in subsequent data to be presented. This detrimental effect of sizing agents to board strength is well known, and to offset this lowering of strength synthetic binders are sometimes added to give the board the desired strength.

Effect of Cooking Time on Board Properties

It was desired to determine what effect cooking time would have on board properties. In this series of experiments 35 percent Douglas fir bark with wood mixtures were prepared, each run furnishing four boards. One run was made as previously described, namely 5 minute steaming period at 90 psig. in the preheating chamber, followed by defiberization. In the second run, the bark-wood mixture was steamed for 30 minutes at 90 psig. in a stainless steel rotating digester, then defiberized as above. All wet laps were hot pressed at 375° F. platen temperature, using 500, 50, and 500 psi. for 2. 3, and 15 minutes respectively. The results are given in Table 3.

Note that the board strengths of the longer cooked material is considerably lower than those resulting when short steaming periods are used. Thus it would suggest that when relatively long cooking periods are employed at high steam pressure, the resulting chips are partially hydrolyzed causing some of the fiber structure to break down. This is further indicated since the pulp yield is materially reduced over what is recovered when shorter cooking periods are used. Lower water absorptions appear also to result with shorter cooking periods. Perhaps, some of the naturally occurring water repellent agents present in the bark are partially removed during the longer steaming period.

Effect of Pressure and Temperature During Pressing Cycle

In order to determine the effect on board properties of specific gravity, which can be somewhat controlled by the amount of pressure and platen temperatures used during the hot press cycle, two runs (9 boards each) were made using 35 percent Douglas fir bark, together with 65 percent Douglas fir wood. The chip mixtures were preheated 5 minutes at 90 psig. steam and defiberized as usual. Platen temperatures of 375° F., and 410° F., were used, the former being a pressure cycle of 2, 3, and 15 minutes at various pressures indicated below, while the latter comprised 2, 2, and 10 minutes at pressures indicated. The results follow in Table 4.

These data indicate that the strength of the board is increased and water absorption and swelling are lowered as the platen pressure is increased. Likewise, as would be anticipated, the specific gravity increases as pressure is raised.

TABLE 3

Cooking Pressure	Time	Pulp yield	Freeness	Caliper	Sp. gr.	Absorption Percent		Swelling Percent		Modulus of rupture
psig.	min.	Percent	sec.	in.		A	B	A	B	psi.
90	5	87.5	36	.241	1.02	9.6	11.4	8.8	9.2	5,423
90	30	71.0	38	.243	1.02	14.0	15.7	7.6	11.2	3,645

TABLE 4

Pressure cycle psi.	Caliper in.	Sp. gr.	Absorption Percent A	Absorption Percent B	Swelling Percent A	Swelling Percent B	Modulus psi.
375° F. Platen Temperature							
250–50–250	.241	0.95	8.9	12.4	5.2	7.3	5,830
500–50–250	.240	1.00	8.2	11.8	5.3	5.8	5,590
500–50–500	.223	1.06	8.2	10.9	5.2	6.5	6,385
410° F. Platen Temperature							
250–50–250	.244	1.00	6.8	9.9	4.8	8.5	5,125
500–50–250	.234	1.03	6.1	8.9	4.0	7.1	6,032
500–50–500	.221	1.06	5.2	8.4	3.0	5.5	6,330

Increased platen temperature appears to lower water absorption, together with slightly greater dimensional stability. It is suggested that as the temperature increases, at a given pressure a greater "flow" takes place, giving greater board densities.

Other Bark Species with Douglas Fir Bark in Hardboard

While the greatest percentage of logs milled at the Oregon Lumber Company at Dee, Oregon, is Douglas fir, small amounts of white fir and hemlock are put through the mill. It was desired to ascertain what effect small amounts of bark from these other species would have on hardboard properties, if they were mixed and processed with the Douglas fir slabs. Several runs were made using Douglas fir bark with white fir bark mixture containing 25 percent of the latter and adding 35 percent of the mixed barks to wood chips. This was repeated with hemlock bark using 25 percent of the latter mixed with Douglas fir bark. Asplund pulp was produced and boards pressed at 375° F. platen temperature using pressing cycle of 500, 50, and 500 psi. for 2, 3, and 15 minutes. The results follow in Table 5.

It would appear that small amounts of other barks tested, i.e. white fir and hemlock, when mixed with Douglas fir bark, produce hardboards with acceptable properties. Thus, slabs other than Douglas fir can be added to the latter for subsequent processing into hardboard, without materially reducing the quality of the hardboard produced.

Wax Content of Douglas Fir Bark versus Water Absorption

It was recently reported that Douglas fir bark contains a benzene-soluble wax, amounting to 5 to 10 percent, based on the dry weight of the bark.[3] It was of interest to run bark-wood hardboards containing barks with known quantities of wax, to determine what effect wax content would have on the water absorption properties of hardboard. Thus, the amount of wax in various lots of Douglas fir bark was determined by extracting the ground bark in Soxhlet extractors for 8 hours with benzene. The loss in weight after extraction, after correcting for moisture content, was calculated as approximate wax content. Undoubtedly, small amounts of other chemical substances are also removed with benzene. Douglas fir bark lot No. 5 was found to contain 3.4 percent wax (benzene soluble) which was the lowest amount found in all barks examined, while Douglas fir bark lot No. 8 contained 6 percent wax, which is more representative of the average wax content found in the barks used. Several 30 and 35 percent bark board runs were made with each of these barks, using platen temperature of 375° F. and pressing cycle of 500, 50, and 500 psi. for 2, 3, and 15 minutes. The results are reported in Table 6 below.

It would appear that as the wax content of the bark increases, the water absorption of the resulting board decreases. The amount of wax

[3] Kurth, E. F., Kiefer, H. J., and Hubbard, J. K. Utilization of Douglas Fir Bark. Timberman, 49, (8): 130–131, 1948.

TABLE 5

Fir bark mixture	Pulp yield Percent	Freeness sec.	Caliper in.	Absorption Percent A	Absorption Percent B	Swelling Percent A	Swelling Percent B	Modulus psi.
Douglas–White 3–1	89.0	42	.234	15.1	16.6	12.4	16.6	5,520
Douglas–Hemlock 3–1	86.0	37	.233	12.0	17.1	7.7	9.5	5,010

TABLE 6

Bark lot No.	Wax in bark Percent	Bark Percent	Absorption Percent A	Absorption Percent B	Swelling Percent A	Swelling Percent B	Modulus of rupture psi.
5	3.4	30	13.5	17.8	11.0	11.5	5,700
8	6.0	30	9.4	13.6	7.3	7.5	6,150
5	3.4	35	10.7	13.3	8.1	10.1	5,322
8	6.0	35	8.0	11.8	7.7	6.9	5,500

to be found in the bark is contingent on environment and whether the bark is from the butt or top log. Kurth et al[3] reported that the butt bark contains the greater quantity of wax and that the content decreases as the top of the tree is approached. It will also be noted, that the higher wax content produced boards of slightly higher strength. This was likewise indicated in subsequent experimental runs on bark of known benzene-soluble (wax) content. Perhaps the extractives in Douglas fir bark act as natural binding agents, as well as water repelling agents. It should be noted that increase in wax content of Douglas fir bark does not decrease board strength, which is contrary to what occurs when increased quantities of sizing agents, either in the form of rosin or wax (emulsion), are used.

Wax-Free Douglas Fir Bark and Water Absorption

If the wax in Douglas fir bark acts as a water repelling or sizing agent in hardboard, then wax-free Douglas fir bark should produce board of high water absorption. Thus it was of interest to extract the bark with solvents to remove various fractions of the total extract and determine effect of each such extracted bark in hardboard on water absorption. It is reported that petroleum ether removes a portion of the wax, and that benzene removes all or nearly all the wax present in Douglas fir bark.[3] Each of these solvents, as well as acetone, which removes more extractives than either of the other two solvents, was used to extract Douglas fir bark. The extracted barks (35 percent) were added to wood chips and processed into hardboard in the usual manner. The platen temperature was 410° F. and the pressing cycle was 500, 50, and 500 psi. for 2, 2, and 10 minutes. The results obtained follow in Table 7.

The petroleum ether extracted bark, in which a portion of the wax was removed, gave a water absorption slightly higher than the unextracted bark. The benzene extracted bark, with practically all the wax removed, gave a board with much higher water absorption than the unextracted bark, while acetone, which removed additional extractive substances, gave the highest water absorption as well as the greatest degree of swelling. Thus, it is apparent that the wax in Douglas fir bark plays an important role in imparting water repellency to hardboard.

Hundred-percent Douglas Fir Wood Hardboard

The best pulping conditions found for bark-wood composition boards in the present investigation (5 minutes preheating of chips processed through the Asplund defibrator followed by pulp refining through the Bauer mill) were repeated using 100-percent Douglas fir wood and boards were prepared to obtain results comparative with the bark-wood boards prepared under similar conditions. Platen temperatures of 375° F. and 410° F. were used, the former having a pressing cycle of 500, 50, and 500 psi. for 2, 3, and 15 minutes, while the latter was treated at 500, 50, and 500 psi. for 2, 2, and 10 minutes. The results of these runs, giving pulp yields of about 91 percent, were as follows:

These data on 100 percent Douglas fir wood fiber hardboard clearly demonstrate that the in-

TABLE 7

Bark used	Extract removed Percent	Water absorption Percent A	Water absorption Percent B	Swelling Percent A	Swelling Percent B	Modulus of rupture psi.
Unextracted	0.0	6.7	9.6	6.0	5.9	6,085
Petroleum ether extracted	2.3	10.2	17.3	6.6	11.1	5,170
Benzene extracted	6.0	39.3	33.4	15.3	14.9	5,880
Acetone extracted	10.2	49.2	43.0	27.5	22.2	5,900

TABLE 8

Size Percent	Freeness sec.	Caliper in.	Sp. gr.	Absorption Percent A	Absorption Percent B	Swelling Percent A	Swelling Percent B	Modulus of rupture psi.
375° F. platen temperature								
0	32	.239	0.98	65.4	60.5	39.3	46.3	6,623
1	32	.234	0.99	11.2	14.8	9.1	14.2	4,920
2	32	.236	1.01	10.2	12.8	8.5	12.1	4,617
410° F. platen temperature								
0	34	.229	0.99	58.8	55.7	29.8	30.0	7,467
1	34	.221	1.03	9.7	11.0	8.5	9.0	5,647
2	34	.232	1.04	8.3	9.9	7.1	8.0	5,065
3	34	.218	1.06	6.6	9.7	5.2	6.2	4,895

corporation of Douglas fir bark is no deterent for producing hardboard with acceptable properties. Results in this laboratory indicate that bark-wood boards can be produced which have strengths superior to straight wood fiber sized boards having comparable water absorptions. When pulping straight wood chips the motor amperage was noticeably higher than when pulping bark-wood mixtures to comparable stock freeness. Preliminary power consumption data were determined on a commercial pulper and it was indicated that perhaps a third less horse power is required to pulp bark-wood compositions than straight wood chips, each of which received the same prepulping treatment.

Properties of Some Available Commercially Produced Hardboard

From time to time, commercially available hardboards made by various companies were obtained and physical properties determined using the same testing methods as employed in this laboratory. The comparative properties of three such type of boards are recorded in Table 9 below.

From the experimental studies reported here it is indicated that the properties of hardboards containing Douglas fir bark compare favorably with those of the commercially produced hardboards tested. It is realized that laboratory scale runs give only indications of what might be expected on commercial scale production. However, some of the laboratory results obtained have been confirmed by semicommercial and commercial test runs and no serious difficulties are anticipated for the large-scale production of hardboard containing Douglas fir bark. A commercial hardboard plant using this new bark-wood process is being erected at the Oregon Lumber Company, Dee, Oregon, by the Blaw–Knox Construction Company.

Economic Advantages of the Bark-Wood Hardboard Process

Several distinct economic factors appear to be favorable to the bark-wood hardboard process. These may be enumerated as follows:

Raw Material

A satisfactory Douglas fir bark-wood hardboard can be produced containing varying percentages of bark composition. Since a relatively large latitude in the quantity of bark used is permissible it is not necessary to remove the bark from the slabwood prior to processing. Thus, debarking equipment is eliminated. The economy involved using this type of raw material will vary, depending on market value of

TABLE 9

Commercial hardboard	Caliper in.	Sp. gr.	Water absorption Percent A	Water absorption Percent B	Swelling Percent A	Swelling Percent B	Modulus of rupture psi.
A-1	.254	0.915	8.4	14.2	8.3	6.7	4,040
A-2	.253	0.925	8.4	13.8	7.9	7.2	4,008
A-3	.246	0.927	9.0	12.8	6.5	8.6	4,500
B-1	.254	0.940	12.6	17.4	14.1	12.2	4,160
B-2	.251	0.965	11.1	16.1	14.0	13.5	4,070
B-3	.249	0.945	10.6	19.0	12.8	17.6	4,840
C-1	.276	0.995	4.3	8.0	5.5	7.7	3,690
C-2	.272	0.990	4.0	7.7	5.2	7.4	4,315
C-3	.210	0.875	11.2	17.3	7.2	7.8	2,930

bark-free wood chips, which are required for previous hardboard processes. It is estimated that the savings will vary from $3 to as much as $12 for each ton of wood being processed.

Electrical Energy

Another item in the hardboard process which contributes to the manufacturing cost is the horse power required in converting the chips to pulp. It was found that considerably less horse power is required to pulp bark-wood mixtures, as compared with pulping straight wood chips. The exact economy in electrical energy is not known, but it is estimated that about 33 percent less power will be required.

Chemicals

In all other commercial hardboard processes certain percentages of sizing agents, such as rosin or wax, together with alum or mineral acids, are required to render the finished hardboard resistant to water absorption and subsequent swelling. When Douglas fir bark is used the usual sizing agents are omitted for the bark acts as an excellent water repelling agent. This is the first wood fiber hardboard process in which no chemicals whatever are required. The economic advantage of this phase of the bark-wood hardboard process will depend on the chemical costs involved in the various hardboard processes now being used. Chemical costs for manufacture of hardboard are said to vary from a minimum of $2 to $8 or more per 1,000 sq. ft. of quarter-inch hardboard.

General

Less water will be required in this new process, since barkwood pulp consistencies of 5 to 6 percent appear suitable for board formation, while present processes require 1 to 2 percent pulp consistency. In hot pressing the wet lap to hardboard less caul releasing compound (lubricant) will be required since the natural waxes and cork cells present in bark act as lubricant in themselves. Thus fewer shut-downs due to boards sticking to cauls is anticipated.

Summary

It has been demonstrated that Douglas fir bark in varying percentages, together with wood, is a suitable raw material for making a quality hardboard. This use of Douglas fir slabwood should be an attractive outlet for the utilization of this waste material by Douglas fir mills. This new bark-wood hardboard process is another step in the further integrated utilization of wood by-products or wood waste.

The use of Douglas fir bark in hardboard composition eliminates the need for adding any chemicals, such as the usual sizing agents, for the bark acts as an excellent water repellent agent. The amount of bark present in the composition appears not to be critical in order to produce a satisfactory, uniform hardboard. It appears that the quantity of bark may vary as much as from 20 to more than 45 percent and still maintain a standard product—hence no need to debark slabwood prior to processing or control the bark content. The bark-wood hardboard process reduces processing cost because (1) raw material is cheap and readily available, (2) less power is required for pulping, and (3) it is the only hardboard process that does not require chemicals.

The Douglas fir region of the western coastal states has abundant quantities of slabwood that are available at a cost relatively low compared to cost of bark-free wood used in present processes. The ample supply of this by-product wood material or waste, plus other economic advantages of the bark-wood process, presents to the lumber mills of this region another process in the further integrated utilization of lumber and pulp mill wastes. This new bark-wood hardboard process can be used in any conventional wet hardboard process plant.

The process developed and described has been covered by patent claims designed to protect the interest of the sponsors of this research program. It is the intention of the sponsors to make the process generally available to the industry at nominal fees. The Blaw–Knox Construction Company, Pittsburgh, Pa., is exclusive agent to license this bark-wood process.

Acknowledgements

The authors are grateful for the assistance and suggestions given by Mr. A. C. Lighthall, Mr. Floyd Carpenter, and Mr. Newell Wright of the Oregon Lumber Company. And the authors wish to thank the Oregon Lumber Company and Blaw–Knox Construction Company, Pittsburgh, Pa., for permission to publish the results of this investigation.

Discussion

Mr. G. E. Tower (Forest Fiber Products Company): I would appreciate having your comment on the amount of time in the press for ¼-inch board; and the kind of size used.

Mr. Anderson: The time in the press was 15 minutes at 410 degrees F. and 20 minutes at 375 degrees F. When product is sized, we use resin size and/or a wax with alum or sulfuric acid. However, as indicated in my talk, when Douglas-fir bark is used, no size is required.

Mr. A. Wehrle (Coos Bay Lumber Co.): Did you run any impact tests on your board?

Mr. Anderson: We did not.

Mr. Wehrle: Was the 14 minutes pressing cycle the actual time the board was in the press? Did it include loading and unloading time?

Mr. Anderson: No, 14 minutes at pressure.

Mr. Wehrle: Have you made any boards larger than 12 inch by 12 inch?

Mr. Anderson: Yes, we have made 4 foot by 4 foot hardboard.

Mr. Wehrle: What is the color of your board?

Mr. Anderson: The color is comparable to Masonite untempered hardboard.

Mr. Wehrle: You remarked that the wax content of the bark varied considerably. How do you control the water resistance properties of the product with this variation in the bark?

Mr. Anderson: While the wax content varies, the overall average wax content is sufficient to maintain low water absorption specifications, together with good strength properties.

Mr. J. H. Grant, Jr. (Burritt Lumber Sales Corp.): Can this process be applied to slabs and edging waste from other species than Douglas fir, and if so, to what extent? Dependent on economic cost to do so, is same process applicable to both hard and softwoods, and to what extent is it economically possible to put such a process of reclamation into effect at small mill productions.

Mr. Anderson: Yes, but small amounts of size may have to be added to give satisfactory low water absorptions. The hardwood barks have not been tried thus far. If the small mills have around 75 tons of wood waste per day, the process should be economical.

Mr. R. F. England (Washington Institute of Forest Products): Have you noticed any difficulties arising from dirt imbedded in the bark? Would there be any obstacle to using slab from dry mills if slab were washed at the hardboard mill?

Mr. Anderson: We encountered no difficulty with dirt in bark. The log should be thoroughly washed prior to entering the mill. Then, as an extra precaution, the slabwood should be also washed to remove any foreign matter prior to being chipped.

Mr. R. W. Miller (Simpson Logging Co.): Did the paracol wax sizing supplement the properties due to the natural wax in the Douglas fir bark, or is the natural wax peculiar in itself?

Mr. Anderson: Paracol wax did lower water absorption, but it also lowered the modulus, the synthetic sizing wax acting like rosin size, it lowered strength of boards proportionately to amount of sizing agent added.

Mr. Grant: Why is the modulus of strength so emphatically stressed in regard to soft and hard board manufacture? When the greatest possible use may well be to simply cover space, conserve labor of installation, and be available in sufficient quality and demand at low cost to make it a competitive item in this use. Also, why has so little been said in regard to moisture-proofing of this product?

Mr. Anderson: Federal specifications for untempered hardboard call for a minimum modulus of 6000 psi. However, many of the available hardboards do not meet this modulus and as you indicated, that strength is not necessary for many applications. It is my understanding that attempts are being made to revise the strength standards for hardboards—to set minimum strengths for various end-uses. In regard to moisture-proofing of our product, we feel that this is a very important property of fiber products, and the hardwood hardboards appear to have better moisture resistance and better dimensional stability than most wood fiber products.

FOREST PRODUCTS RESEARCH SOCIETY

Some Studies of Sawdust-Synthetic Resin Combinations for Hardboard Manufacture

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Division of Forest Products, Commonwealth Scientific & Industrial Research Organization, Australia

The development of experimental technique for the laboratory production of small test specimens of sawdust-synthetic resin boards using untreated sawdust and dry synthetic resin powders is described and the results of exploratory tests showing the effect of a number of factors on the quality of the final product are given. The development of a preforming technique for the production of large test samples with limited equipment is also described. Microscopic examination of some boards was made with special reference to associated physical properties.

Introduction

IN THE Australian sawmilling industry nearly 12 percent of the log volume appears as sawdust. It is estimated that more than 50,000 tons are produced per month, of which perhaps 30 percent only is being used effectively at the present time for fuel and other purposes. Supplies are widely distributed, but there are several centers where large quantities are available.

At the time this experimental work was commenced very little published information on the properties of sawdust-synthetic resin combinations was available: and apart from some very limited work carried out with a phenolic molding powder at the Division of Forest Products in 1937, practically no information on the probable behavior of Australian species existed.

Preliminary inquiry showed that the price of synthetic resins, particularly urea-based types, was high locally, but after consideration of costs, availability, and water resistance a commercially available solid cresylic resin was selected for the initial work.

It was decided to limit the sawdust waste used to that of light colored "ash" type eucalypts. Radiata pine was also used to a limited extent for reference purposes and in the production of large test specimens. These wastes were readily available and were believed to be representative of a high proportion of existing and potential waste in Australia.

ACKNOWLEDGMENT

The author wishes to make special acknowledgment of work of Mr. C. V. Lansell, who was responsible for the major portion of the laboratory work on this project. Thanks are also due to several members of the staff of the Seasoning Section who assisted in the study.

Grateful acknowledgment is made of the work of Mr. I. J. W. Bisset of the Wood Structure Section, for the development of technique in microscopic examination, and the staff of the Section of Mathematical Statistics for assistance in interpretation of results.

Development of Experimental Technique for Laboratory Production of Small Test Specimens

A laboratory type Carver press was fitted with electrically heated platens and a simple molding die was made to support the sawdust-resin mixture during the forming and pressing operation. The mold body and bottom plate (see Fig. 1) when assembled formed a simple

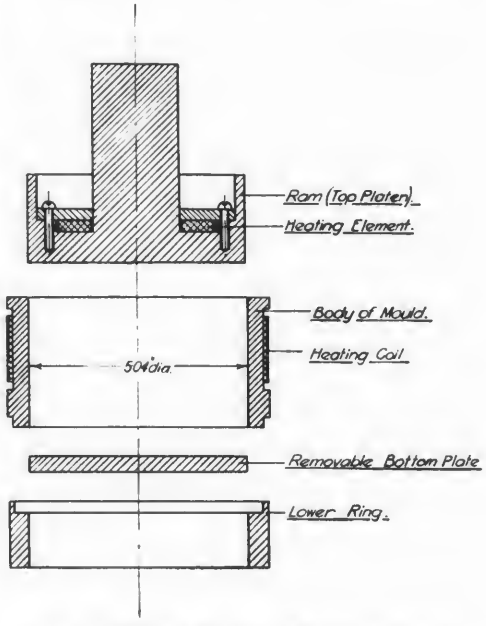

Fig. 1.—Molding die for small test specimens.

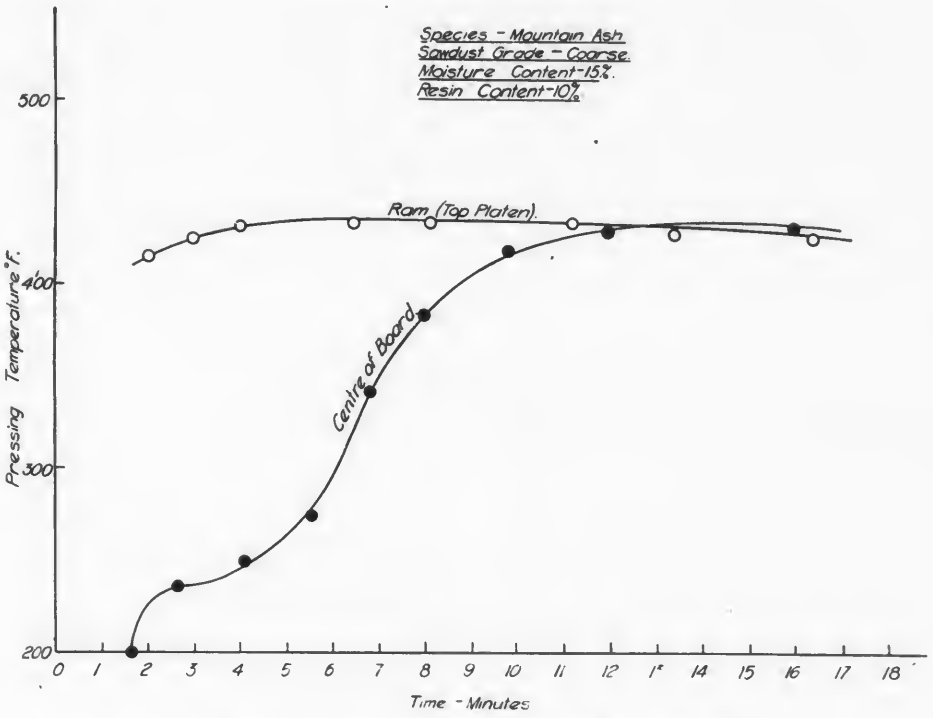

Fig. 2.—Typical time-temperature relationship during pressing.

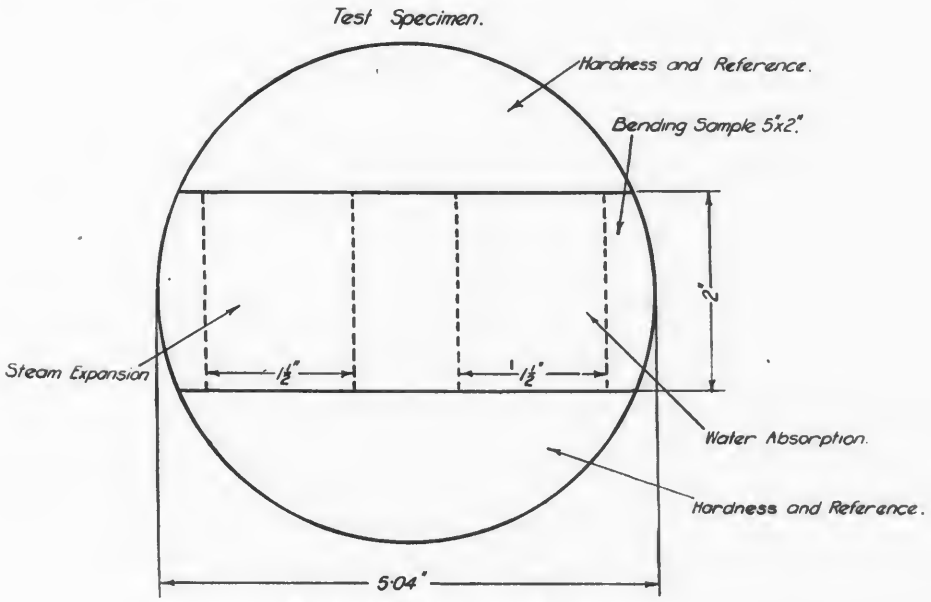

Fig. 3.—Method of sampling specimens.

container for holding the mixture during pressing. Breather holes were provided in the ram and a screen was placed under the ram to allow gases to escape.

To improve temperature distribution the ram and mold body were later fitted with electrical heating elements of 600 and 300 watts respectively. The use of thermostatic control and energy regulation, made it possible to control the temperature of all parts of the specimen discs to within 5° F. to 10° F. of the temperature specified for any particular operation.

Copper-constantan thermocouples at first with a potentiometer and later with a 6 point millivoltmeter were used to observe the temperatures of press platens, ram, mold body and test specimen during the pressing operation. To measure temperatures within the board, thermocouples were run through a hole in the mold body and positioned in the mix. Fig. 2 shows a typical time-temperature curve obtained on a test specimen.

The general procedure used for making a test specimen was as follows:

(a) Weighed amounts of sawdust and resin were thoroughly mixed and placed in the mold body which had first been preheated to the selected temperature.

(b) The mold, with thermocouples in place, was then loaded into the press as rapidly as possible, and the required pressure applied within one minute and maintained.

(c) After release of pressure the test specimen was ejected quickly and allowed to cool in air. A light dusting of calcium stearate powder was used to prevent sticking in the mold.

All resin contents were expressed as a percentage of the oven dry weight of the sawdust used and the small test specimens normally contained 100 grams of wood substance.

Exploratory Tests

Small Laboratory Samples

Owing to the small size of the samples, tests were restricted to bending strength, water resistance, resistance to steam, hardness and density. The test specimen was sampled as shown in Fig. 3 after the thickness of the specimen had been adjusted to a nominal ¼ inch by sanding the screened face. In the bending test, pieces 5 inches by 2 inches were supported at 4-inch centers and loaded at midspan at a rate of 200 pounds per minute. Samples 2 inches by 1½ inches were obtained from each end of the broken piece for water absorption and steaming tests. The remaining segments of the original disc were used for hardness tests and for general reference purposes. The moisture absorption test followed the general procedure outlined in (E. S.–19) of A. S. T. M. specifications for Thermal Insulating Boards 1944, except that the preliminary treatment at 160° F. for 24 hours was omitted, and a 2- by 1½-inch specimen used instead of the 12-inch square specified.

The steaming test samples were weighed, measured and steamed under saturated conditions at atmospheric pressure for periods of one-half hour, one hour and two hours. Calculations for dimensional and moisture content changes were then made on the same basis as for the water absorption test. It was decided to use the results of increase in weight after a 48-hour soaking period, and of increase in thickness after the 1-hour steaming period for the study of effect of process variables on the board properties.

Hardness tests were carried out in duplicate by dropping a 1-inch steel ball from a height of 6 feet on the test sample and the diameter of impact was recorded by placing a sheet of paper together with a sheet of carbon paper on top of the board. The diameters of the marks were then measured. This test is described in *Appendix G.* of the "Building Industries National Council Code of Practice for Laying of Magnesite Composition Flooring and Dadoes"—March 1938.

The effects of pressing time, temperature, sawdust-particle size, pressure, resin-particle size and moisture content of sawdust have been analysed on approximately 100 exploratory test samples. Unless otherwise stated the results given in the paper are for a pressure of 500 psi.

Three grades of sawdust were used and these were separated through test sieves standardized in accordance with B. S. Specification 410–1943. Unless otherwise stated the results described refer to "ash" type hardwood sawdusts.

The grade sizes of sawdust used are shown in Table 1.

TABLE 1

Grade of sawdust	Passed through Sieve No.	Passed through Aperture inches	Retained on Sieve No.	Retained on Aperture inches	Mean size shown on figures inches
"Coarse"	8	0.125	14	0.0474	0.0860
"Medium"	14	0.0474	23	0.0236	0.0350
"Fine"	23	0.0236	72	0.0083	0.0159

The commercial resin used, which was of a p-m-cresol-formaldehyde type, was ground to "coarse" and "fine" grades (see Table 2).

TABLE 2

Grade of resin	Passed through Sieve No.	Passed through Aperture inches	Retained on Sieve No.	Retained on Aperture inches
"Coarse"	23	0.0236	40	0.0166
"Fine"	72	0.0083	--	------

In discussing the results of the individual factors, a selection of samples has been made in which all factors other than those under immediate consideration were, as near as possible, in the most favorable condition. In some instances this has led to severe limitation in the number of results used.

Effect of pressing time. Results are shown in Fig. 4. Using a medium grade of sawdust at 15 percent moisture content, with a 10 percent resin content and a temperature approximating 400° F., good strength values with a mean modulus of rupture of a little more than 5,000 psi. were obtained in a pressing time of 10 minutes. Pressing times of 15 and 25 minutes gave similar strength values. There was no improvement with longer times, and a single specimen pressed for 50 minutes fell in the same strength range. It is just possible that a slight falling off in bending strength occurs with the long pressing time at this temperature. Bending strength figures generally were between 4,000 and 7,000 psi. although one exceptional specimen gave a figure of 7,800 psi. A pressing time of 7 minutes gave far lower figures, presumably because of incomplete setting of the resin.

A very high water absorption was obtained after 6 minutes setting time, and even after a 10 minute pressing time (by which time good strength was developed), water absorption was still found to be rather high. Considerable improvement was shown with 15 minutes pressing, but beyond this time the improvement became very small and, it is doubtful whether the slight additional improvement shown in Fig. 4

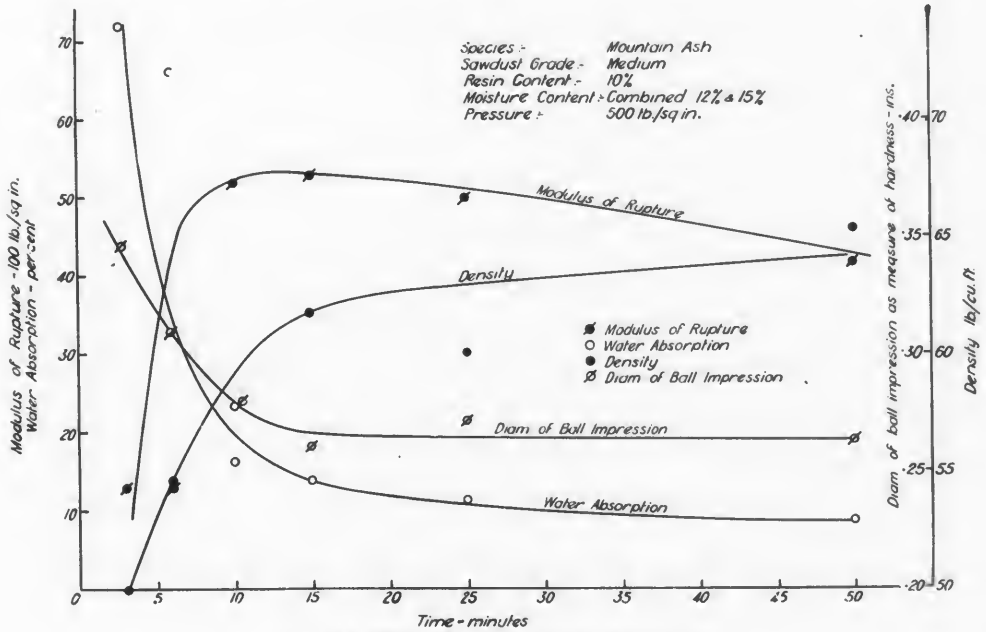
Species :- Mountain Ash
Sawdust Grade :- Medium
Resin Content :- 10%
Moisture Content :- Combined 12% & 15%
Pressure :- 500 lb/sq in.
Modulus of Rupture
Density
Diam of Ball Impression
Water Absorption
Modulus of Rupture - 100 lb./sq in.
Water Absorption - per cent
Diam of ball impression as measure of hardness - ins.
Density lb/cu ft
Time - minutes

Fig. 4.—Effect of pressing time on properties.

is significant, although observations after 50 minutes pressing are in accordance with this trend. The results for board stability during steaming were slightly more erratic but showed a similar trend clearly indicating that a pressing time of 15 minutes is a minimum for reasonable stability.

The hardness tests showed no improvement after 15 minutes pressing.

Effect of temperature. It was decided to regard the ram and platen temperatures, as observed at 6 minutes or more after application of pressure, as representative of critical conditions.

The effect of temperature on bending strength was not marked provided that the resin was properly set, and little difference in bending strength could be detected between samples prepared at 320° F. to 440° F. assuming other factors were held constant. This appears to be true for pressing times ranging from 10 to 25 minutes.

The effect of temperature on stability (both water absorption and board expansion during steaming) is apparent (see Figs. 5 and 6) and all results showed a trend favoring the higher temperatures. Samples made with a resin content of 10 percent and pressed at 320° F. for 25 minutes (see Fig. 5) compare most unfavorably with similar samples pressed at 400° F. to 430° F.; and a similar trend was noted in boards pressed for 12 minutes (see Fig. 6), although the curve appears rather steeper for the shorter pressing time, indicating that in this case stability falls away more rapidly at a given temperature. The best sample of the series was pressed at 450° F. but water absorption almost invariably fell below 20 percent with samples containing 10 percent of resin when pressed at 420° F. or higher.

The hardness and density of the specimens increased with increasing temperature at the 12-minute pressing time. Where 25 minutes pressing time was used, this correlation was lost, but mean hardness results are shown for reference.

Burnt areas occurred in a number of specimens at high pressing temperatures, and generally set the limits of temperature for different sets of test conditions. The burning appeared to occur with destructive distillation of both wood and resin, and was apparently associated

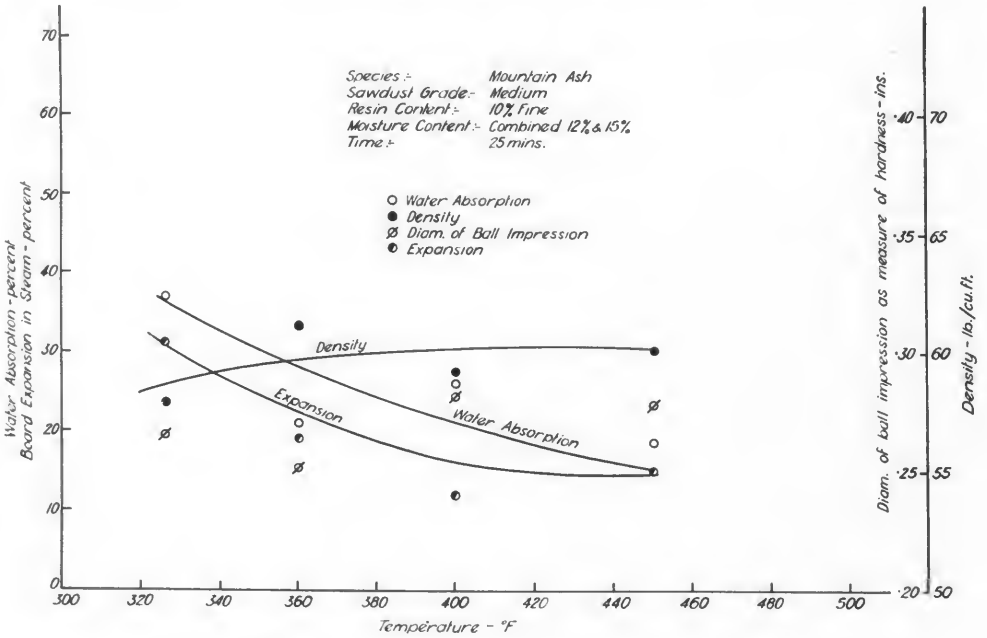

Fig. 5.—Effect of temperature on properties—25-minute pressing time.

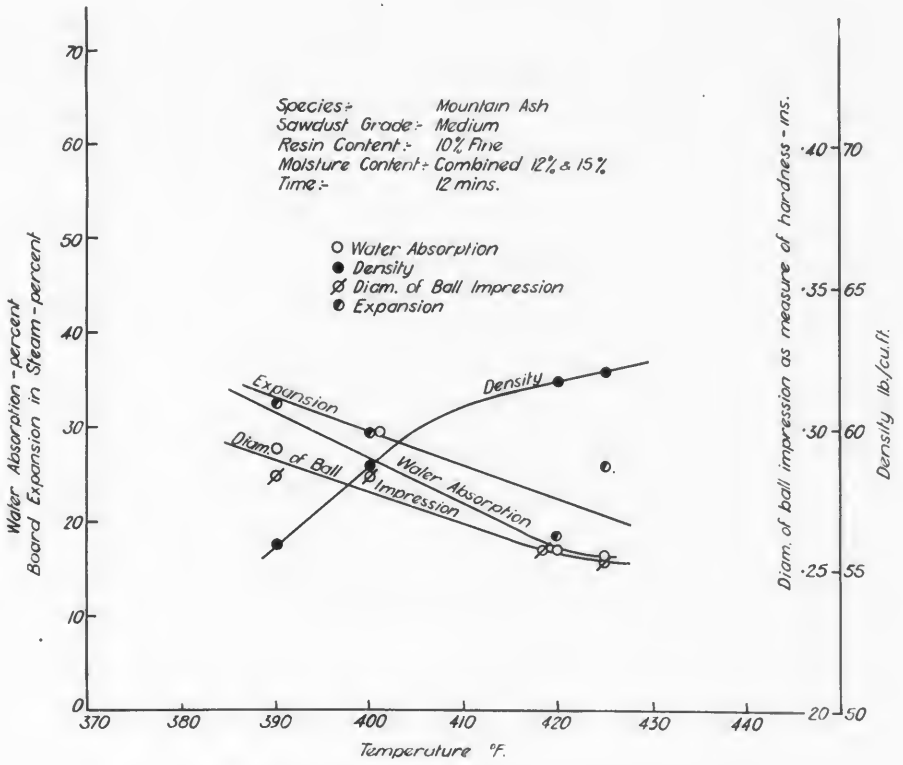
Species :- Mountain Ash
Sawdust Grade :- Medium
Resin Content :- 10% Fine
Moisture Content :- Combined 12% & 15%
Time :- 12 mins.
Water Absorption
Density
Diam. of Ball Impression
Expansion
Water Absorption - percent
Board Expansion in Steam - percent
Diam. of ball impression as measure of hardness - ins.
Density lb./cu.ft.
Temperature °F.

Fig. 6.—Effect of temperature on properties—12-minute pressing time.

with the exothermic reaction of resin polymerization.

Attempts to use 20 percent resin content at pressures of 500 psi. produced burns at 400° F. and above; in the 10 percent resin content groups at 500 pounds pressure the lowest maximum platen temperature at which burns were produced was 430° F. and a number of boards gave no burning at 450° F. At pressures of 1,000 psi. with 10 percent resin content, burns were obtained at 370° F.

It may be of some interest to note here that in work on the large test samples with the strip heater (referred to later in the paper) where hexamine catalyst was used with a "Novolac" type of cresylic resin, the tendency to burn was minimized by reduction in the amount of catalyst. This is probably due, in part at least, to a retardation of setting rate, and hence of the rate of heat liberation.

The effect of temperature upon color was very marked. At 300° F. very little discoloration occurred, but at 400° F. the boards were quite brown, and at temperatures over 420° F. dark brown shades were obtained with hardwood sawdust. Pine sawdust produced a lighter shade but the trend was similar.

Effect of resin content. Increase in strength with increase in resin content from 2 to 10 percent is almost linear (see Fig. 7) but at higher resin contents the curve flattens. Results for density show a similar trend.

Reduction in water absorption with increasing resin content for the same sample group, is also shown in Fig. 7. Thus there is a steady improvement to 10 percent resin content but little change at 15 percent. Hardness also improves with increasing resin content to 10 percent.

Effect of pressure. At a 10 percent resin content pressures of 200, 500 and 1000 psi. were used with a medium grade of sawdust. The results showed increasing strength with increasing pressure as demonstrated in Fig. 8.

Results for water absorption at the 10 percent resin content showed little difference between 500 and 1000 psi. but the sample prepared at 200 psi. was more than twice as absorbent. The steamed samples did not show any decided trend.

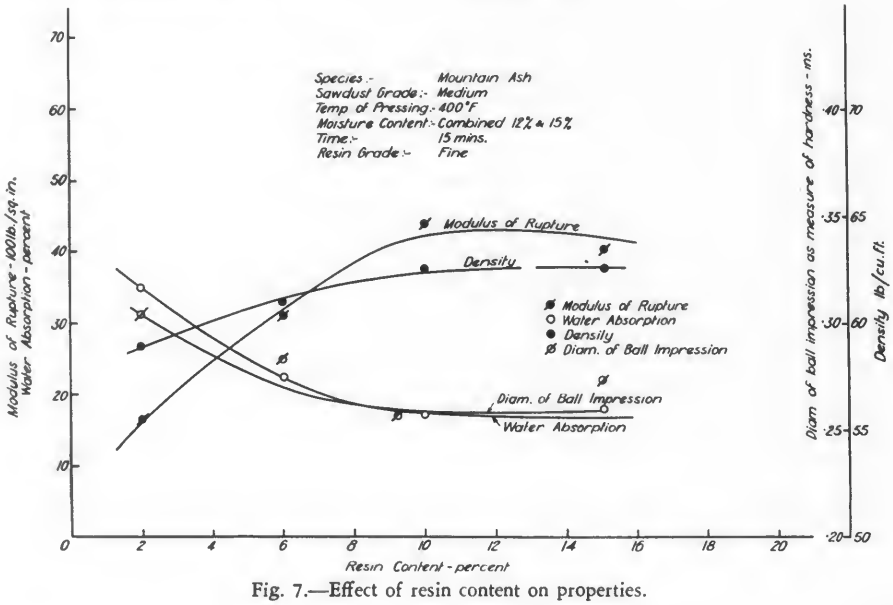
Species :- Mountain Ash
Sawdust Grade :- Medium
Temp of Pressing :- 400°F
Moisture Content :- Combined 12% & 15%
Time :- 15 mins.
Resin Grade :- Fine
Modulus of Rupture
Density
Modulus of Rupture
Water Absorption
Density
Diam. of Ball Impression
Diam. of Ball Impression
Water Absorption
Modulus of Rupture - 100lb/sq.in. Water Absorption - percent
Diam of ball impression as measure of hardness - ins.
Density lb/cu.ft.
Resin Content - percent

Fig. 7.—Effect of resin content on properties.

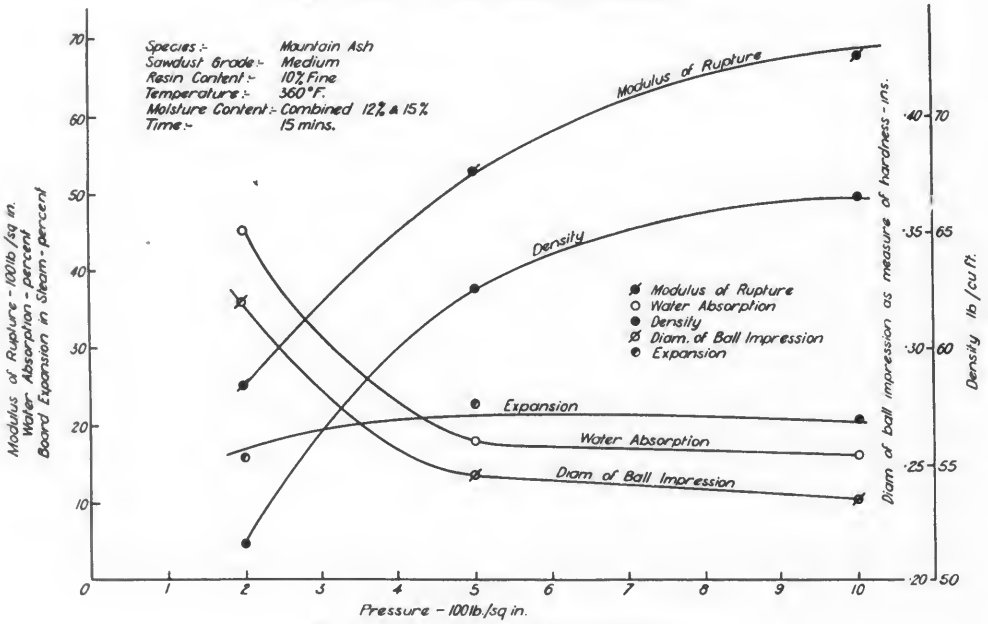
Species :- Mountain Ash
Sawdust Grade :- Medium
Resin Content :- 10% Fine
Temperature :- 360°F.
Moisture Content :- Combined 12% & 15%
Time :- 15 mins.
Modulus of Rupture
Density
Modulus of Rupture
Water Absorption
Density
Diam. of Ball Impression
Expansion
Expansion
Water Absorption
Diam. of Ball Impression
Modulus of Rupture - 100lb/sq in. Water Absorption - percent Board Expansion in Steam - percent
Diam of ball impression as measure of hardness - ins.
Density lb/cu ft.
Pressure - 100lb/sq in.

Fig. 8.—Effect of pressure on properties.

The similarity of density and strength curves is of interest, and hardness increased with increasing pressure.

Effect of particle size. The medium grade sawdust gave the highest bending strength results with both coarse and fine grades of resin. The mean values obtained for eight observations with each sawdust and resin grade are plotted in Fig. 9.

There is evidence of a linear relationship between water absorption and particle size favoring the small particles: fine-sawdust-fine-resin combinations showing greatest consistency in results.

The steamed specimens gave very inconsistent results which are not shown in the figure.

Density increased with reduction in sawdust particle size, and the fine resin produced higher density in all grades.

Effect of sawdust moisture content. The indication was that best strengths are not attained until the moisture content of the sawdust is in the vicinity of 10 or 12 percent. The values plotted in Fig. 10 are averages of two or more observations and the most consistent results were obtained at a moisture content of 12 percent.

Results for steamed specimens were reasonably consistent, and there was little evidence of significant differences over the range of moisture contents tested.

The similarity between the strength and density curves is of interest since the result leads to the inference that a reduced plasticity of the wood at low moisture content can have very marked effects on board density and strength. Resin behavior may also be involved to a limited extent.

Effect of species. The limited number of samples made from pine sawdust has not allowed full comparison of their properties with those of samples made from hardwood sawdust (ash eucalypts) but there is no evidence of any marked difference in strength, although there is an apparent difference in stability.

In the hardwood specimens there was very little difference between the percentage increase in thickness from one hour's steaming, and the percentage increase in weight after 24 hours'

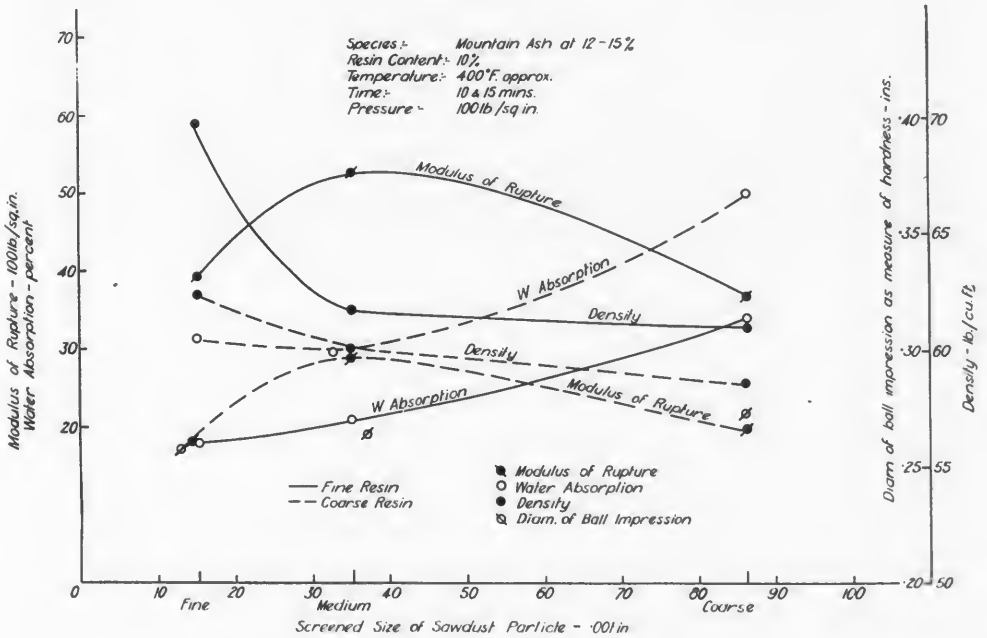

Fig. 9.—Effect of particle size on properties.

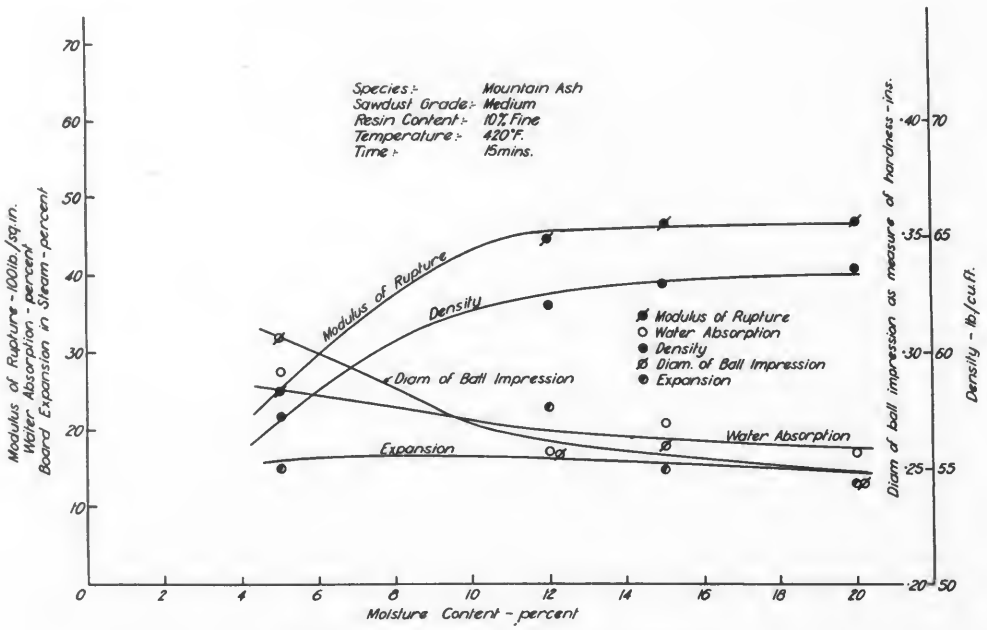

Fig. 10.—Effect of moisture content on properties.

water immersion, but in the case of the pine the water absorption percentages are two to three times the values for percentage expansion in steam.

Large Test Samples

In order to make a better assessment of the quality of the material it was decided to produce boards of a much larger area in a single opening steam heated hydraulic press with a platen area of 36 inches by 20 inches and with auxiliary strip heating. a preforming method was adopted to simplify equipment and minimize side flow during final pressing. Figs. 11 and 12 show the details of the equipment used.

Boards made with this equipment received a final pressing for 40 minutes, after a preforming operation carried out at 200° F. and 500 psi. pressure for 6 minutes.

The long pressing period was unavoidable with the strip heater arrangement, but most boards still showed a slight tendency to warp after removal from the press, possibly because of asymmetric heating resulting from the presence of the screen against one side of the strip heater.

Some 45 boards were produced by this method and the properties of matched material of these boards were in good conformity with those of the small specimens described previously. The large boards are being subjected to additional tests including wear tests as a floor surface but results are not yet available.

Microscopic Examination With Special Reference to Physical Properties

Samples containing medium grade sawdust and fine resin in the proportions of 2, 6, 10, and 15 percent were used in this study, and also one sample which had a coarse resin content of 10 percent. In all cases these samples were pressed at 400° F. for 15 minutes at a pressure of 500 psi.

Two techniques for examination were developed and in all cases observations were made on surfaces normal to the board face.

In the first technique used a solid section was examined by reflected light after first smoothing the specimen with a heavy sliding microtome and staining lightly with safranin. In the second method a heavy sliding micro-

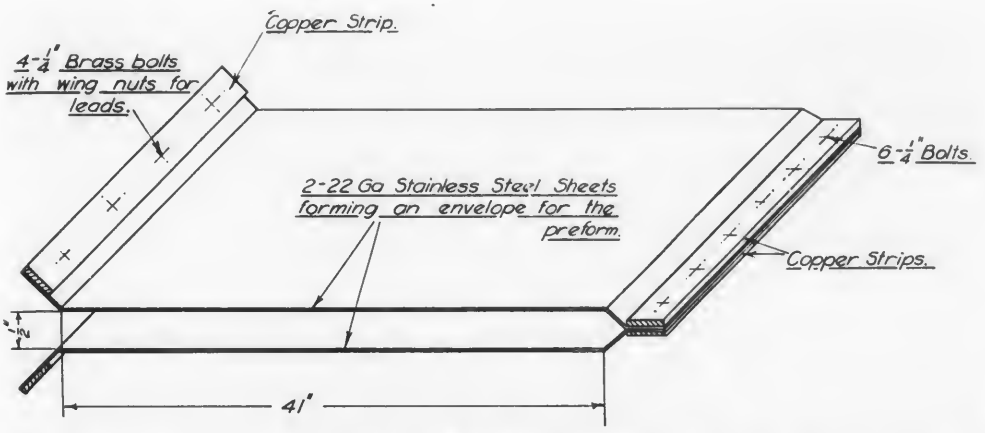

Fig. 11.—Strip heater assembly.

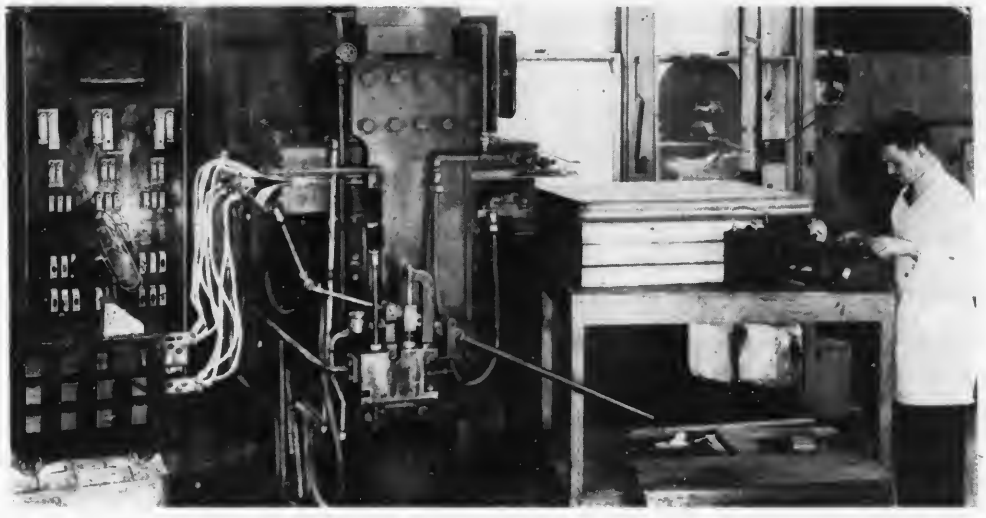

Fig. 12.—Strip heater assembly during pressing operation.

tome was used to cut matched samples of sawdust resin board to a thickness of 20 μ: again a safranin stain, consisting of 0.1 percent safranin in 60 percent alcohol, was used. These sections were examined by transmitted light. It was found that the 20 μ sections were far more satisfactory for the purpose although reference to the blocks assisted in drawing conclusions regarding fractures.

Perhaps the most impressive feature was the degree of orientation which had occurred in the particles; in almost all cases the long axis of the sawdust particle was in the same plane as the face of the board. This is well illustrated in Fig. 13.

The second point of major interest was that the amount of flow or plastic deformation occurring in the particles was sufficient to close nearly all gaps in the specimens.

Other features were—

(a) In specimens with 2 percent fine resin content only isolated particles and resin films were visible.

(b) In specimens with 6 percent fine resin content groups of sawdust were well bound together by thin films of resin between the faces.

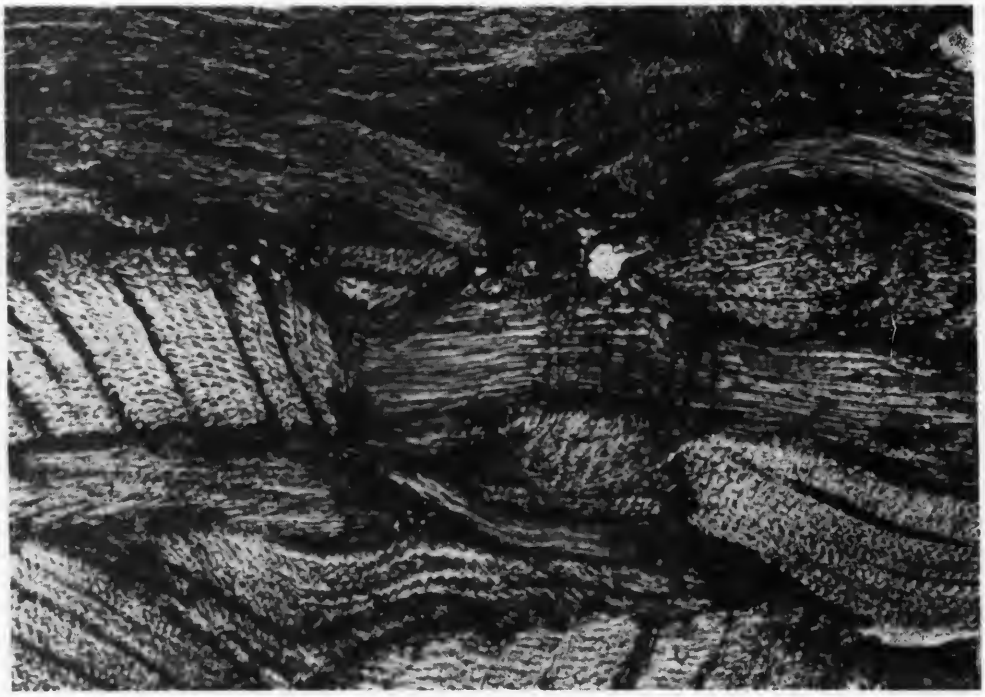

Fig. 13.—Enlarged cross section of board made with medium-grade sawdust and 10 percent resin content and pressed at 500 psi.

(c) In specimens with 10 percent fine resin content there was a marked improvement in the distribution of resin film. In a number of small cavities small accumulations of resin were visible, indicating that adjacent sawdust particle surfaces had been completely covered with resin. The resin had apparently melted to a liquid of low viscosity and penetrated the open ends of fibres. In some cases this penetration was noted to the extent of 30 fibre diameters. The wood ray cells appeared to be even more readily penetrated by the resin. A section of 10 percent resin content material is shown in Fig. 13.

(d) In specimens with 10 percent coarse resin content the poor resin distribution was most apparent. There was generally a much reduced film of resin between particles yet, in certain cases, quite large accumulations of resin in cavities.

(e) In specimens with 15 percent fine resin content there did not appear to be a great increase in the number of thin resin films between closely packed particles. There was, however, a marked increase in the resin accumulation in small cavities.

Conclusions

The examination of the exploratory test samples prepared in the Carver press made the importance of certain factors clear, particularly the requirement of high pressing temperatures to obtain stability. Indications were that temperatures of 430° F. to 440° F. at 500 psi. and 10 percent resin content, approached the practical maximum if a tendency to the development of burns in the board is to be avoided. This result was confirmed in the larger boards made with the strip heater.

There were also strong indications that extension of the heating time beyond that necessary to cure the resin was needed to obtain high stability, and 15 minutes pressing appeared to be the minimum effective period.

The most favorable resin content for the medium grade of sawdust used was in the

vicinity of 10 percent, and little improvement in properties occurred with higher resin content. Microscopic examination provided interesting confirmation of this, since sections of samples showed a resin film covering most of the contact surfaces of the sawdust particles.

When the moisture content was 10 percent or higher, pressing at 500 psi. at 400° F. or more caused a very considerable increase in density as compared with the original wood, and at the same time insured intimate contact between particles and effective use of the resin.

Moisture content appeared most important in its effect on plasticity, and at 500 psi. moisture contents significantly lower than 10 percent were apparently insufficient to ensure good contact between sawdust particles and specimens were lower in density and strength. There were indications that the moisture content of the sawdust must also have a very important effect on the rate of heating of the board, but the exploratory samples did not permit examination of this factor.

It was found that particle size of the solid resin was most important and results generally were strongly in favor of a resin particle size passing a 72-mesh sieve, which was the minimum grade tested.

Microscopic examination of the pressed board gave confirmation that, with a coarse resin grade, resin distribution was unsatisfactory. On the other hand, there were clear indications that the distribution obtained with a fine resin grade was highly satisfactory.

Sawdust grading gave stability properties favoring medium and fine grades, and a feature of special interest was the degree of orientation of particles that occurred during the pressing operation. This resulted in the longer axes of most particles being more or less alined with the surface of the board. This points to the desirability of having the longest axis of the sawdust particle corresponding to the fibre direction. Although the importance of this factor has not been investigated, it is likely that, for many sawdusts, a milling operation followed by suitable screening would produce a far more desirable condition than simple sieving.

It is very possible that study of the sawdust particle size and shape could lead to a board with satisfactory properties at lower resin contents. Specially prepared raw materials could lead to even lower resin requirements, and the study of the optimum size and shape of particle for the developing of particular properties at specific resin contents should lead to significant economies in production.

Discussion

Mr. John H. Grant, Jr. (Burritt Lumber Sales Company Inc.): What are the problems of producing building blocks from wood waste, using a waterproof binder suited to the intended use? I have seen such a product, and believe that it can be produced cheaply from sawdust. If the product were available in varying degrees of hardness and could be remilled the material would lend itself to many uses.

Mr. J. W. Gottstein: In order to produce building blocks on a commercial scale having strengths and stabilities approaching the best obtained in the laboratory work outlined in the paper, and using untreated sawdust and synthetic resin as the raw materials, would probably require considerable modification to the simple forming technique described. The principal reason is that sawdust-resin combinations, with suitably low resin contents, show very poor flow characteristics during pressing. In addition, careful moisture content control and possibly electronic preheating would be necessary in order to reach suitable resin curing and sawdust stabilizing temperatures at the interior of the block in a reasonable time.

Many other binders have been tried in combination with wood waste, and building blocks using hydraulic cements are being manufactured commercially: the well known Durisol product of Switzerland is an example. Control of physical properties within certain limits is obtained by selection of waste, proportion of cement and forming pressures. Although raw materials are cheap, setting of the cement is slow and labor costs can be high. For exterior use special consideration must be given because of movement associated with the hygroscopic properties of untreated wood particles. Special block designs and construction methods have been evolved and it is understood that in suitable applications very good results have been obtained.

FOREST PRODUCTS RESEARCH SOCIETY

Effect of Molding Temperature on the Strength and Dimensional Stability of Hardboards From Fiberized Water-Soaked Douglas-Fir Chips

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Chemical Engineer
and
P. K. Baird
Chemist
Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

The experiments reported herein demonstrate that Douglas-fir hardboard prepared from pulps produced by fiberizing water-soaked chips can be dried and heat-treated in one short operation in a hot press at temperatures in ex.ess of 200° C. Hardboard so produced has a higher modulus of rupture and a better dimensional stability than that produced at lower temperatures.

Introduction

THE manufacture of hardboard from wood fiber usually involves steam-cooking and fiberizing wood chips, sizing the stock, and forming pulp sheets and hot-pressing them to hardboard. These boards can be improved in flexural strength and dimensional stability by impregnation with drying oils and by heat treatment (tempering), or by heat treatment alone (*8*). In some instances synthetic resins are incorporated in the pulp stock to bring about these improvements (*1*, *2*).

Heat treatment of hardboard has been pioneered in the Scandinavian countries and is now general practice in Sweden (*7*, *11*). This treatment probably stems from the observation that the effect of heat upon the hygroscopicity of wood is permanent (*15*, *17*). The operation is usually conducted at temperatures below 160° C. because of the danger of spontaneous combustion in the kiln (*11*). In practice, the usual range is from 120° to 140° C., and the time consumed is from 4 to 5 hours. The treatment makes the boards stronger but more brittle (*7*).

The exothermic decomposition of wood has been found to be appreciable at temperatures above 270° C. (*6*, *16*). This report presents the results of a study of the drying and heat treating of hardboards in one operation in a hot press somewhat below that temperature, that is, in the range of 180° to 240° C.

Material

The pulp stock used in this study was prepared from the incipiently decayed heartwood of an old-growth Douglas-fir log (shipment 2655, lot 2), but chemical analysis and sulfate-pulping experiments on this wood indicated it had but little, if any, degradation (*10*). This log was representative of wood that had been infected by a fungus, *Fomes pini* (white pocket rot), and that is not, therefore, generally suitable for lumber manufacture. Profitable utilization of such wood is desirable, since extensive forest stands of this type exist in Oregon.

The chips were water-soaked and fiberized in a 36-inch double-rotating disk mill under conditions that favored brushing more than cutting. The energy consumed in milling was about 44 horsepower-days per ton of wood (moisture-free basis).

The drainage characteristic of the stock was determined in a Williams precision-model freeness tester. An 8.6-gram sample of stock, moisture-free basis, was used to simulate board-making procedure (*5*), and the test was conducted at a temperature of 20° ± 1° C. The observed freeness value of 146 seconds is approximately the upper limit permissible for conventional board-machine operation (*5*), and is,

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

moreover, undoubtedly greatly in excess of that of stocks usually employed in hardboard plants. The pulp fractionation was conducted in a multiple-diaphragm plate screen (Appleton selective screen) (*13*). The weight of the test sheets on the basis of a ream of 500 24- by 40-inch sheets was 340 pounds. The bursting and tensile strengths were corrected to a sheet density of 0.3 gram per cubic centimeter on the basis that these strengths vary directly with density (*3*). The screen analysis of the pulp and the strengths of test sheets were:

Screen analysis:	Percent
Retained on 24-mesh screen	31.3
Retained between 24- and 42-mesh screen	18.0
Retained between 42- and 80-mesh screen	12.3
Retained between 80- and 150-mesh screen	14.3
Passing through 150-mesh screen	24.1
Bursting strength ---------- Pts./lb./ream	0.063
Tensile strength ---------- Lb./sq. in.	280

Hardboard Preparation

Hardboards, nominally 1/8 inch in thickness and 8½ inches in diameter, were prepared by hot-pressing wet, unsized pulp mats. The pulp mats were formed in an 8.5-inch-diameter pressure mold described previously (*14*). A calculated amount of pulp and a portion of the water were mixed with a high-speed propeller-type stirrer. The stock was charged to the mold, diluted to 1 percent consistence, and, before the mat was formed, was agitated with compressed air. The mats were cold-pressed at 750 pounds per square inch before they were hot-pressed.

Each prepressed mat was placed on a 16-mesh galvanized-wire screen between copper cauls and hot-pressed in a 125-ton press that had 14- by 14-inch platens. The press was heated by means of a Dowtherm unit to attain the high temperature used. A thermocouple, inserted in the mat about 1 inch from the edge, was used to determine the temperature of the pressing. The wire and the top caul were lubricated with montan wax to prevent the board from sticking to them. In all cases a 1-minute breathing period was included in the pressing schedule, during which interval the pressure was dropped 100 pounds per square inch. In most instances this interval occurred between the second and third pressing minutes. In the 180° C. series, the breathing period was between the third and fourth minute.

Twelve groups, of four hardboards each, were made for the time-temperature series. The boards were pressed at 750 pounds per square inch at maximum temperatures of 180°, 200°, 220°, and 240° C. for periods of 5, 25, and 75 minutes. The approximate time to maximum temperature varied from 5 minutes at the highest temperature schedule to 8 minutes at the lowest temperature schedule.

Hardboard Testing

The boards were tested for flexural properties, toughness, dimensional stability, and water absorption. Each board furnished two static-bending specimens, 6 by 1½ inches, cut from the center portion; two toughness specimens, 6 by ½ inches; and two dimensional-stability specimens, 3 by 1 inches. One of the static-bending specimens from each board was subsequently cut to 3 by 1 inches and used for the water-absorption test.

Static Bending

The specimens were tested in static bending according to the Forest Products Laboratory procedure (*4*).

The modulus-of-rupture values were adjusted to a specific gravity of 1.0 on the basis of varying as the square of the density (*18*). The modulus-of-elasticity values were also adjusted to a specific gravity of 1.0. It was assumed that the stiffness of the boards varied as the 1.5 power of the specific gravity on the basis of the variations observed in wood (*9*) and in fiberboards (*18*). The specific gravity of the specimens varied from 0.96 to 1.09, and the averaged values of the groups varied from 1.00 to 1.06.

Toughness

The toughness tests were made on the toughness-testing machine, of intermediate capacity, that is available at the Forest Products Laboratory. This machine, originally designed for testing wood, is of a pendulum type and, as adapted for these tests, measures energy required to break a ½-inch-wide unnotched nominal 1/8-inch specimen on a span of 2½ inches.

The boards were approximately 0.150 inch thick, and the toughness values were adjusted to a thickness 0.125 upon the assumption that the values varied as the square of the thickness.

The adjustment did not cause any significant changes in the relative toughness values.

Dimensional Stability Against Moisture Vapor

For the dimensional-stability test, specimens were conditioned for 24 hours in an oven maintained at a temperature of 50° C., cooled in a desiccator, weighed, and measured for thickness and length at marked points to the nearest 0.001 inch. The samples were then placed in an atmosphere maintained at 97 percent relative humidity and at a temperature of 80° F. for 34 days, after which they were weighed and measured. The specimens were air-dried and were then oven-dried at a temperature of 50° C. for 24 hours, and were then cooled in a desiccator, after which deviations from the original conditioned weights and measurements were noted.

The dimensional-stability data, except linear expansion, were adjusted to a specific gravity of 1.0. Ogland (*12*) found that swelling and recovery increased with density but that linear expansion was not affected. It was assumed that for small variations in density the dimensional-stability values varied directly with the density. The average specific gravity of the various groups of specimens ranged from 1.01 to 1.03.

Water Absorption

Water-absorption test samples were weighed and immersed for 24 hours under 1 inch of distilled water maintained at a temperature of 70° ± 5° F. At the end of the immersion

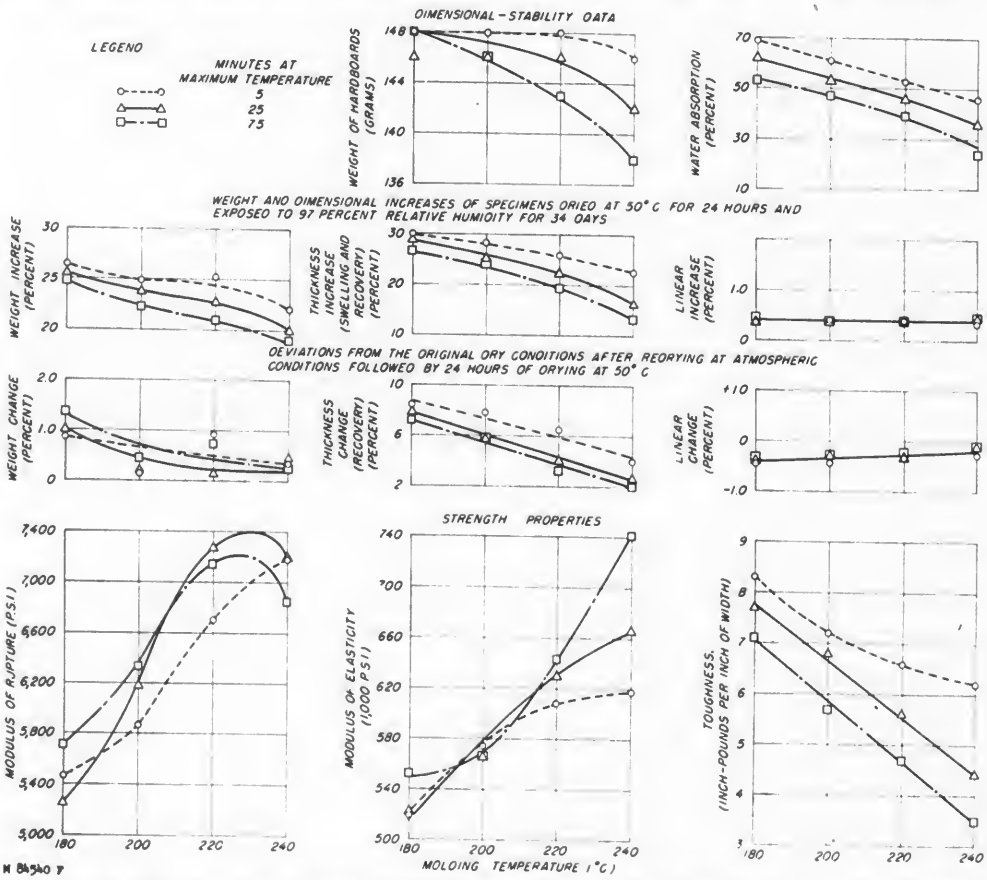
DIMENSIONAL-STABILITY DATA
LEGEND
MINUTES AT MAXIMUM TEMPERATURE
5
25
75
WEIGHT OF HARDBOARDS (GRAMS)
WATER ABSORPTION (PERCENT)
WEIGHT AND DIMENSIONAL INCREASES OF SPECIMENS DRIED AT 50° C FOR 24 HOURS AND EXPOSED TO 97 PERCENT RELATIVE HUMIDITY FOR 34 DAYS
WEIGHT INCREASE (PERCENT)
THICKNESS INCREASE (SWELLING AND RECOVERY) (PERCENT)
LINEAR INCREASE (PERCENT)
DEVIATIONS FROM THE ORIGINAL DRY CONDITIONS AFTER REDRYING AT ATMOSPHERIC CONDITIONS FOLLOWED BY 24 HOURS OF DRYING AT 50° C
WEIGHT CHANGE (PERCENT)
THICKNESS CHANGE (RECOVERY) (PERCENT)
LINEAR CHANGE (PERCENT)
STRENGTH PROPERTIES
MODULUS OF RUPTURE (P.S.I.)
MODULUS OF ELASTICITY (1,000 P.S.I.)
TOUGHNESS (INCH-POUNDS PER INCH OF WIDTH)
MOLDING TEMPERATURE (°C)

Fig. 1.—The effect of molding temperature on the strength, dimensional stability, water absorption, and weight of hardboards made from fiberized water-soaked Douglas-fir chips.

period, the excess surface water was removed by means of a damp cloth and the samples were weighed again. The weight of absorbed water was expressed in percentage of the initial weight.

Discussion of Results

The temperature of molding was found to have a pronounced effect on the properties of hardboards. The flexural properties of the boards were substantially increased by increasing the molding temperature from 180° to 240° C., while the toughness was markedly reduced. Increasing the molding temperature increased the dimensional stability in thickness (swelling and recovery) and decreased the water absorption of the boards. These changes were accompanied by a decrease in weight and darkening of the dried boards. The data are graphically presented in Fig. 1.

The modulus of rupture of the hardboards plotted against maximum temperatures for molding periods of 5, 25, and 75 minutes gave a series of curves that show or indicate a maximum flexural strength of 7,200 to 7,400 pounds per square inch. The temperature of the maximum strengths decreased as the time of molding increased. Thus it appears that at the 5-minute period the probable optimum molding temperature would be 250° C., at the 25-minute period about 230° C., and at the 75-minute period about 227° C.

Molding temperatures higher than 200° C. greatly stiffened and embrittled the boards, as indicated by the increase in modulus of elasticity and the decrease in toughness. This effect was not so pronounced, however, at the 5-minute period as in the longer heating period.

The percentage changes in the properties of the hardboards brought about by raising the molding temperature from 180° to 240° C. for the several periods are given in Table 1. Linear expansion was unaffected by the temperature or time of molding. With a molding time of 5 minutes the increase in temperature caused an increase of 32 percent in flexural strength, 19 percent in stiffness, 33 percent in water resistance, and a decrease of 27 percent in thickness. These changes were accompanied by a slight loss in the weight of the boards and a decrease of 25 percent in toughness. Molding for periods at maximum temperatures of 25 and 75 minutes produced further improvements in stiffness, water resistance, and thickness stability, but little or no improvement in flexural strength and an additional decrease in toughness.

Ogland (*11*) found that hardboard heated under molten metal decreased in flexural strength, while hardboard heated in air under comparable conditions increased 20 to 30 percent. This difference can be attributed to the retention of pyroligneous acids in the board by the heat of molten metal and the subsequent degradation of the material. The effects of heat treating on hardboard in a press were found to be similar to those produced by heating in air. Ogland (*11*) has presented data to indicate that the changes in the properties of hardboard are due to the action of heat on the hemicellulose component.

Incipient fungus growth after 34 days' exposure in an atmosphere at 97 percent humidity and at a temperature of 80° F. was exhibited by all boards molded at 240° C., irrespective of the length of the molding period. Boards

TABLE 1.—THE EFFECT OF INCREASING MOLDING TEMPERATURE FROM 180° TO 240° C. ON THE PROPERTIES OF UNSIZED HARDBOARDS FROM FIBERIZED WATER-SOAKED DOUGLAS-FIR CHIPS

Change in properties on increasing the molding temperature from 180° to 240° C.

	Strength				Dimensional changes						
					Conditioned state[2]			Redried state[3]			
Time at maximum temperature	Modulus of rupture	Modulus of elasticity	FPL toughness	Water absorption	Length	Thickness (swelling and recovery)	Weight	Length	Thickness (recovery)	Weight	Weight loss[1]
Minutes	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
5	+32	+19	—25	—33	0	—27	—16	—25	—52	—67	1.4
25	+37	+28	—43	—42	0	—42	—22	—75	—66	—50	4.1
75	+20	+34	—49	—55	0	—50	—24	—67	—71	—79	6.8

[1] Weight of hardboards produced at 180° C. taken as 148 grams in all cases.
[2] Specimens dried originally at 50° C. for 24 hours. Conditioned at 97 percent humidity and 80° F. for 34 days.
[3] Deviations from the original dry conditions after redrying at atmospheric conditions followed by 24 hours of drying at 50° C.

molded at temperatures of 180°, 200°, and 220° C. were unaffected. Whether the observation has significance or not is not known. However, since heat treating of wood has been advocated as a means of improving its decay resistance (*16*), this converse observation is recorded.

Summary and Conclusions

Strong hardboard was made from stock prepared by fiberizing water-soaked Douglas-fir chips. The hardboard was made without resorting to steam-cooking, the incorporation of synthetic resins, or prolonged heat treatment of the board. The drying and heat-treating were achieved in one short operation in a hot press by means of high molding temperatures. Since the temperature of exothermic decomposition is not appreciable below 270° C., it appears that molding temperatures in excess of 240° C. could be used. Under such conditions the molding could be less than 10 minutes.

The increases in flexural strength and in stability in thickness (swelling and recovery) were comparable to those obtained in the commercial 4- to 5-hour kiln-drying procedure. The flexural strength increase was, however, considerably below that secured by means of tempering. Raising the maximum temperature from 180° to 240° C. for a 5-minute molding period increased the flexural strength 32 percent; stiffness, 19 percent; water resistance, 33 percent; and decreased swelling and recovery 27 percent upon humidification. Molding for periods at maximum temperatures of 25 and 75 minutes gave further improvements in stiffness, water resistance, and thickness stability, but little or no improvement in flexural strength and an additional decrease in toughness. Linear expansion was unaffected by the termperature or time of molding.

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TECHNICAL SESSION VII

Wednesday, June 28, 1950, 1:30 P. M.

General Subject: Softwood Plywood Review

Chairman: O. Harry Schrader, Jr., Managing Director, Douglas Fir Plywood Association, Tacoma, Washington

Recorder: Arthur L. Mottet, Research Engineer, Long–Bell Lumber Company, Longview, Washington

O. H. Schrader, Jr., J. F. Hamilton Presiding

Douglas Fir Substitutes for the British Columbia Plywood Industry

John Bene
Western Plywood Co., Ltd., Vancouver, B. C.

The supply of Douglas fir logs yielding good face veneers is dwindling rapidly in British Columbia. There is no shortage of logs suitable for core veneers. Other B. C. coniferous species are not too well suited for face veneer production. Face veneers from hardwoods of the East and South of North America, and from the Tropics, and from hardwood trees grown on the West Coast, will permit the industry to maintain present production and expand further.

Status of Douglas Fir Peelers

THE annual cut of Douglas fir logs on the British Columbia coast amounts to one and one-half billion board feet. Ten percent of this is used for plywood, producing the equivalent of about 300 million square feet on a three-eighths inch basis. This is sold for more than thirty million dollars. Twenty-five hundred men are employed to convert logs into plywood.

If you ask a plywood plant log buyer what kind of log he wants, he will tell you "only the best". Further questions will reveal that the true minimum requirements are: a log with diameter of more than 20 inches, reasonably round, reasonably straight, free from large checks with as few knots as possible. Usually a log with knots on one side, 1½ inches or less in diameter, is acceptable.

The most important requirement is undoubtedly the texture. Only old-growth, close-grained fir logs make good face veneer. If the log comes from a rapid-grown tree, the veneer will be rough and the difference between summerwood and springwood will be too pronounced. If the log comes from a tree grown on a poor site, exposed to the wind, it will have too hard a grain, and often show spiral grain and shakes. If the log comes from an aged tree it may contain rot pockets, incipient decay, or the wood may be too dry to cut into smooth, high-grade face veneers. The most suitable logs are those from trees grown in a sheltered location with good soil, in dense stands 200–400 years old. In such favorable conditions about 50 percent of the stand may be suitable for rotary cutting; the balance will be too poorly shaped, too knotty or otherwise too defective, to make its use for plywood worthwhile.

It is estimated by the writer that about 5 percent of the total merchantable fir timber in British Columbia will make good peelers. Even by the most optimistic estimates, the old-growth fir timber will be cut out within 25 years and the top grade timber is being cut twice as fast as the average for the species.

So called "second-growth" fir grown in managed stands, probably will not yield satisfactory face veneers. A rotation of 80–150 years will be too short a time to develop a good veneer log, and the growth rate in a managed stand will probably be too fast to make a truly satisfactory veneer. Within ten years most plywood plants will be forced to look for face material other than fir, and some plants much sooner than this.

It can be argued that the technique of utilizing low-grade logs, jointing the narrow, clear veneer components, patching veneers, and the like will enable us to use a much larger percentage of fir logs, and we can, therefore, extend our supply. Bear in mind, however, that with the development of hardboards and coreboards, made from granulated wood and wood fiber at about one-half the present cost of plywood, the chief reason for buying plywood will be its attractive, workable face veneer. If the quality of the face grade veneers is lowered too much, and thereby detracts from their decorative value, synthetic materials will be substituted for plywood.

There is more fir plywood produced on this continent than all other types combined. The reason for this has been: (1) the adequate accessible supply of large-sized logs, (2) the

ease with which such logs can be converted into plywood (they can be rotary-cut without steaming or other preparation; they can be dried within very wide temperature ranges and to very low moisture content and still stay flat; and it is relatively easy to bond them), and (3) fir plywood is moderately light, warp-resistant, and reasonably attractive, and it is produced in uniform grades and standard sizes.

Fir plywood, however, has a number of disadvantages over other types of plywood and in fairness these should be mentioned. The pronounced difference between springwood and summerwood makes it difficult to finish; the grain will show through even under many coats of paint, and it does surface check easily if exposed to extreme changes of temperature and humidity.

If the assumption is correct that existing Douglas fir peeler log supplies will be exhausted soon, and that few peelers will come from the young, managed forests, then industry must look for substitute materials or, in due course, close shop.

Other West Coast Conifers

So far investigation has been centered mainly on the use of coniferous species other than fir. There is a huge amount of hemlock and cedar available from old-growth, rather high-quality stands. If these woods could be turned into good plywood in existing plants, although it might not solve our problem, it would prolong the supply substantially. Unfortunately, there are many difficulties to be overcome in using either hemlock or cedar. Green hemlock veneer is much wetter than fir veneer, so that the plant drying capacity must be increased to sustain fir production figures. Veneer lathe knives must be ground to a very long bevel in order to cut hemlock veneers smoothly. On the other hand hemlock knots are extremely hard on knives and will chip the long-bevelled knife easily. Hemlock from many districts cannot be cut smoothly, at least not without steaming, and when sanded some of the grain will shell out. Even surface-clear logs will frequently contain a large number of bark pockets. Plywood made with hemlock cores will not be quite as warp-resistant as fir-cored plywood.

One advantage of hemlock plywood is its lower shipping weight which results in considerable freight savings when it is shipped over long distances.

There are few cedar logs which can be peeled readily. Only very old cedar logs are surface clear, and many of these contain heart rot which prevents the log being held in a lathe. Quarter slicing is found to be a more satisfactory method of making clear cedar veneers but this is a slow, costly process.

The true firs (balsam, noble fir, etc.) are another group of woods which have been used to a small extent for plywood manufacture. These species present much the same problems as hemlock.

It should be emphasized that a continued and practically unlimited source of good plywood core material exists now and will exist in the future. A slow-grown or even reasonably fast-grown fir with small, tight knots will make an easily dried, easily bonded core which is fairly light in weight and resistant to twisting.

Hardwoods

Attractive face veneer for fir core-stock will come more and more from hardwoods grown partly in Canada and the United States and partly in the tropics. An increasing amount of synthetic decorative and abrasion-resistant facing materials will be used also.

One advantage of hardwoods for faces is that these can be grown more favorably in managed stands. Due to the cell structure of hardwoods fast growth and a consequent high percentage of summerwood does not affect the uniformity of the wood. As a matter of fact, ring porous hardwoods are tougher if they are grown faster.

The most obvious source of supply for hardwood veneers is the eastern and southeastern United States and the eastern provinces of Canada. A great many plants there make veneers from birch, maple, elm, yellow-poplar, gum, and other species. Even now a fair amount of these veneers is used for facing fir cores. The production of these east-west combination panels may be expected to increase further, but there are many difficulties to overcome. Hardwood logs are bucked mostly to 10–16 foot lengths in the woods. They are very tapered and of relatively small diameter. Therefore, it is wasteful and difficult to produce a large percentage of 8-foot long face veneers.

The great proportion of fir plywood is produced with the grain of the face veneer running in the 8-foot dimension. In many cases it would be possible to make a panel equally useful, and only slightly more expensive, if the grain direction was reversed so that the face veneers would need be only 4 feet long. The acceptance, by the public, of these so-called short-grain panels is one step that must be achieved before the manufacture of hardwood-faced panels can increase substantially.

Another point against a rapid increase of hardwood faces on fir cores is the fact that a large percentage of hardwood veneers produced is unsuitable for face stock because it is too defective. The eastern and southern furniture and plywood plants can use low-grade veneers together with high grade, but west coast plants want to purchase high-grade veneers only.

Several attempts have been made by west coast plywood plants to control eastern veneer producers and direct their long and high-grade veneers to the west coast. In most cases it has been found more profitable to merchandise all of the veneers in the east.

There is better opportunity to secure suitable face veneers from tropical countries. Many trees in the tropics grow in the shape of an umbrella. Between the air roots and the first horizontal branches there is often a clear trunk of 60 feet or more which, in many instances, is suitable for the production of very high-grade veneers. One serious difficulty is that the time elapsing between the falling of the tree and the manufacture of the logs into veneers must be kept to a minimum; otherwise, insect infestation will substantially reduce their value. In general these tropical areas must rely on seasonal river transportation to bring the logs to the mill, the deterioration in transit is unpredictable and generally great.

West Africa is the most important area where logs, veneers, and plywood of tropical species are produced today. In the Belgian Congo, and in French and British African colonies, large firms are operating lumber, plywood, and veneer mills, and almost daily new ones are added to their number. Unfortunately for North America the market for their products is excellent in Europe because the plywood can be bought for soft currency. Consequently the producers are not too anxious today to cater to North American markets.

The Philippines do supply a substantial amount of hardwood in the form of logs and veneer. There are large, unexploited timber resources of very suitable softwoods and hardwoods in Central and South America, and in the South Pacific. When the political situation becomes more stable there will be an increased flow of logs and veneers from this part of the world.

Perhaps the least spectacular but a potentially important source of face veneers is from hardwood logs grown in the western part of North America. On the West Coast hardwoods do not grow in large, clear stands and the total volume shown by cruising is only a small percentage of the total timber volume. There is a fairly large volume of cottonwood (*Populus trichocarpa*) growing along river banks and on islands in shallow rivers. Without management, much of it is either too poorly shaped, too knotty or too old to be of any use other than for pulp. It is estimated that not more than 3 percent of the total merchantable volume of cottonwood can be cut economically into veneers.

Birch (*Betula papyrifera var. occidentalis*) grows throughout British Columbia except for Vancouver Island. Usually it is interspersed with other species and has a tendency to sprout several stems from the same root, thereby growing like a bush and developing several crooked, poorly shaped trunks. If birch stands are thinned, the remaining trees will grow very quickly and develop high-grade logs suitable for veneer in 40 to 60 years.

Substantial amounts of maple (*Acer macrophyllum*) and alder (*Alnus rubra*) grow in British Columbia. In unmanaged stands only a small percentage (sometimes only a fraction of 1 percent) will develop a trunk suitable for veneer; however, all respond very well to management, and the volume of hardwood peelers could be increased within a relatively few years.

Little has been done on the West Coast to establish hardwoods which are not native. I believe very much could be achieved. Black walnut, yellow-poplar, hard maple, and a great many other species, will grow readily here, and would make excellent plywood material in one-

half the time that is required for a coniferous tree to become merchantable.

Very promising experiments have been conducted in the hybridization of new varieties of hardwoods that will combine fast growth with excellent texture and good form. In Denmark, where the climate is similar to that of the Pacific Northwest, a species of poplar which will increase an inch in diameter and 5 to 8 feet in height every year, is grown in fairly large stands. It would not take many acres of plantations of this type to supply the entire face requirements of a plywood plant.

It should be recognized that hardwoods cannot be used for plywood faces in exactly the same way and with exactly the same equipment as fir veneers. Most hardwood logs deteriorate rapidly in storage; they will not float readily over an extended period, and should therefore be stored completely submerged in water. This requires expensive large storage basins where the water level can be regulated, and where a crane can cover every part of the storage area.

Most hardwood logs must be steeped in warm water or be steamed before being cut into veneers. Accurate control of this heating process is required to produce uniform, smooth veneers. Changes on the lathe will be necessary because the conventional roller bar will give inadequate control over the cut. A nose bar should be substituted.

Most hardwood veneers surface check and warp easily if abused in drying. The initial moisture content of hardwoods is greater than that of Douglas fir. Therefore, longer dryers operating at lower temperatures than for fir should be used. Glues used for the bonding of hardwoods to coniferous cores must be designed specifically for that purpose. Hardwoods, generally, are cut into much thinner veneers than fir. They do not require so much sanding because they are cut smoother, but it is important that they be bonded to a well-cut and well-patched core of uniform thickness and that the panels be sanded with great care.

Discussion

Mr. R. W. Wellwood (University of British Columbia): Would the speaker elaborate on the suitability of hybrid poplars, especially those developed in Denmark, as a source of peeler logs.

Mr. Bene: Populus vernirubens, a high grade poplar developed in Scotland and grown in large scale in Denmark, will increase its diameter in excess of one inch per year, and will grow about five feet in height yearly. It is an even-textured wood which makes it suitable as raw material for veneer and plywood production.

Mr. R. C. Fraunberger (Philco Corporation): The East offers very little consolation to the fir plywood industry for face stock. Face stock is becoming in very short supply in eastern hardwoods. The tropics do not offer a much better picture because of politics. The best solution is local species, or raw material at home.

Mr. Bene: We must not overlook the importance of providing for the production of face veneer logs in future forest management plans.

Mr. F. W. Guernsey (Forest Products Laboratory, University of British Columbia): What are the possibilities of using red alder for face veneer?

Mr. Bene: Clear alder will make good face veneers, but in unmanaged alder stands there are usually only one-half percent of the volume suitable for peeler logs.

The Manufacturing of Pine Veneer

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Idaho white pine and ponderosa pine are processed into two types of veneers—rotary cut stock and sliced stock.

The rotary operation has to do with the log selection, transportation, log washing, cutting to block size, movement into veneer plant, barking, scaling, lathe operation, reeling, unreeling, green clipping, green chain sorting, drying, dry chain sorting, patching, glue application, edge gluing, jointing, dry clipping, sizing, and shipping. The slicing operation has to do with flitch and cant selection, transportation to veneer plant, dip tank treating, spraying in the storage room, steaming, flitch cleaning, slicing machine set-up, trimming, drying, clipping, edge gluing, panel lay-up, and shipping.

Rotary Cut Method

BEFORE proceeding to a detailed description of the various steps in the manufacturing of veneers it may be well to establish a definition of the often misunderstood word "veneer". The definition that seems to serve best, is that "veneer is timber in the form of a thin layer of uniform thickness produced by slicing, sawing, or rotary cutting." This paper will have to do only with the sliced and rotary cut veneer.

In order to produce smooth tightly cut veneer a great deal of care must necessarily be given to the selection of the log in the woods. Pine logs are selected in many cases even before the tree has been felled. The tree is marked with red or white paint and after felling it is inspected closely for defects not permissible in a peeler block. A No. 1 pine peeler log should have 50 percent face stock, a No. 2 pine peeler should have 33 percent face stock, and a No. 3 pine peeler is considered a core log. Logs should be selected with knots that do not exceed 2½ inches in diameter. Such defects as ring rot, shake, spiral grain, splits, checks, and dead wood are not permissible in peeler type logs. Peelers which have a marked difference in density between one side and the other will not give a high yield of veneer. The problem of using freshly-cut logs varies a great deal with the size of the operation and the distance the logs have to be transported to the veneer plant. It is not advisable to allow peeler blocks to float in the pond for a prolonged period before being used because this practice has a tendency to cause unequal moisture content between the part of the log that is submerged and the part that is exposed to the atmosphere. Where the veneer plant is a part of a sawmill operation care must be given to the proper cutting of the log to length, so that in the event that a log contains one or two typical peeler blocks, the remainder will be long enough to be sent to the sawmill and cut into the conventional lengths desired in lumber.

The method of thoroughly washing a log with water under pressure and then raising it out of the water for inspection before cutting it into peeler-block lengths, is advantageous from several angles. It enables the selector to inspect the log from all sides, causes much of the loose bark and dirt to be removed before going to the barker, and results in an all around better opportunity to eliminate undesirable blocks.

After the log has been carefully selected it is important that a good job of barking is done in order to save the valuable sapwood and to clean the log thoroughly so as to save excessive wear and tear on lathe knives. The newly developed compression-head barker works very satisfactorily on pine logs, because it consists of a smooth cylindrical roller which tends to push the bark off rather than chew it off as many other barkers do.

From the barker the block is transferred to the lathe where it is scaled and the actual making of veneer begins. Some operations do the scaling at two or three different places. The practice of scaling the log in the pond, through the chain saw and then again at the lathe is followed in many plants. Others feel that scaling at the lathe only is sufficient.

The lathe operation is a very important part of veneer preparation. The operator should be a man who has a knack with machinery. He

should be patient, alert, dependable, and one who takes great pride in his work. The cutting of veneer has been and is still considered more of an art than an exact science. There are certain principles which must be adhered to if good, smooth-quality veneer is to be produced. A veneer lathe must be provided with a means of rotating the log against a knife, a means of exerting pressure on the log as it rotates in a line parallel to the knife, and a means of advancing the knife into the log at a predetermined rate. The knife acts as a wedge and the wood in the form of a sheet passing over the knife would be split rather than cut from the log if pressure were not applied to the log to compress the fibres at the knife edge. From the foregoing statement certain rules can be stated as follows:

Rule No. 1

Use the longest knife bevel which will give a satisfactory cutting life between grinds when cutting the hardest grains normally encountered in the wood being cut. It also follows that the keener the knife edge, the smoother will be the cut surfaces.

Rule No. 2

Set the knife edge level with the center line of the lathe spindles so that every point along the knife edge lies on the same center line. Every point along the edge of the knife must lie in a common straight line which, itself, must lie in a horizontal plane passing through the center of rotation of the block.

Rule No. 3

The line of contact of the pressure plate or roller with the block must be parallel in all planes with the line of the knife edge.

Rule No. 4

When using a roller pressure bar, the center of the roller must be in a plane which passes through the knife edge and forms a 12 degree angle with a plane which is perpendicular to the knife bevel. The average normal position of the knife bevel is approximately vertical. The normal angle of the knife bevel is approximately 20 degrees.

Rule No. 5

The minimum thickness of veneer which can be cut with a given diameter roller will actually depend upon the optimum pitch angle and the optimum angle of knife bevel for a given set of conditions. Specifically the minimum thickness which can be with a ¾-inch diameter roller is 1/10 inch; with a ⅝-inch diameter is 1/12 inch; with a $\frac{9}{16}$-inch diameter is 1/24 inch.

Rule No. 6

The optimum pressure to be applied is a minimum pressure which will hold the knife in the cut and produce given veneer whose thickness is equal to the actual feed per revolution.

Rule No. 7

The optimum pitch angle is that which provides minimum bearing of the knife against the block and, at the same time, avoids all tendency for the knife to chatter or cut "washboard." If the knife leads into the block excessively, a scraping rather than a cutting action results which causes chatter and rough cut veneer. If the knife has excessive "heel" or "bearing", excessive pressure is built up between the block and the knife, resulting in thick and thin veneer, as the excess pressure builds up to a point where the knife bends and removes greater than normal thickness. The use of excess "heel" and/or excess pressure requires excess torque to rotate the block resulting in split or bored out blocks.

In addition to the preceding set of rules there are also certain cutting techniques that must be religiously followed in the production of well-cut veneer.

1. It is imperative that the need for precision be appreciated and stressed at all times.
2. The lathe itself must be kept clean at all times.
3. The mechanical condition of the lathe must be maintained. Slack and play must be kept out of the spindle bearings and adjustment of the caps must be controlled without fail.
4. The knives must be accurately ground to a standard height, angle of bevel, and degree of concavity.
5. The roller bar assembly must be kept clean and free from pitch.

6. The roller bar should be constantly checked for local wear and replaced if the diameter is worn more than 0.010 inch in local spots.
7. The cap of the roller bearing block must be maintained to permit the roller to revolve freely but with a minimum of clearance.
8. A point and a blank scale segment should be provided for the pressure setting, once the setting lines for the normal pressure for each thickness has been determined from experience.
9. A micrometer gauge should be provided for obtaining the proper setting of the height of the pressure roller to the knife edge in accordance with a tabulation of the optimum height for each veneer thickness.
10. Gauges should be supplied to insure that the knife edge and the pressure roller lie in parallel vertical planes.

It is not difficult to vary slightly a single factor while keeping all others constant, and thus determine the optimum setting for each factor for each thickness and species to be cut. It cannot be overstressed that in this operation, which requires quality cutting, each and every setting and adjustment must be a *precision* setting. This means: precision maintenance; precision in cleanliness; precision knife grinding, using a micrometer; precision in alignment of pressure cap to the knife carriage (with gauges); precision in setting heights of roller in respect to knife edge using micrometer gauge; precision in alignment of roller to knife with feeler gauges; precision in setting pitch to proper graduation; and precision in setting pressure to proper graduation.

Following the principles, rules, and techniques of good lathe operation comes the set-up procedure. It may be done best by the following procedure.

1. See that both way surfaces and spindle lines lie in a common horizontal and vertical plane; that the knife bevel is correct; that there is no slack in the feed screw bearings and no play between the feed screws and feed screw nuts; that the main bearing is adjusted to provide minimum running clearance; that there is no excessive wear between the spindle and sleeves and no wear between the slide blocks and the knife carriage trunions; that the pitch rollers contact the pitch tracks; that the feed gearing is set for desired thickness; and that there is no roller bar assembly in the main pressure cap and no knife holder attached to the knife carriage.
2. Run carriage back and forth through its full travel and see that way and pitch track surfaces are clean and free of exuded pitch. Check surfaces in main pressure cap for cleanliness. Check set screws for free turning. Check surfaces on the knife carriage for cleanliness, rust, and raised spots. Check knife holder screws for proper oiling and performance.
3. Bolt two of the gauge plates to knife carriage, one at each end. Use gauge blocks to check alignment of main pressure cap to secure preferred alignment.
4. Secure roller pressure bar assembly from grinder room and check for cleanliness, "bugs" on seating surfaces and roller clearance.
5. Install roller bar assembly.
6. Secure knife and holder assembly from grinder room and check for cleanliness, "bugs" on seating surface, position of knife in holder, angle of bevel and sharpness of knife.
7. Install knife and holder. Adjust with hoist bar. Start clamp screws by hand and set same with impact wrench. Check fit of knife against knife carriage feeler gauge.
8. Adjust roller with relation to knife edge.
9. Back off roller until pointer indicates proper gap to insure cutting proper thickness. Check with feeler gauge.
10. Set each end of roller with micrometer gauge.
11. Recheck gap between roller and knife with feeler gauge.
12. Set knife pitch for species and thickness to be cut.

The lathe is now ready to cut veneer. Slight variations in the pitch and pressure settings may be required as indicated by the sheet of veneer and the condition of block surface. Pressure and pitch adjustment, knife honing, relationship of roller to knife, size of roller bar, and correct knife bevel will vary from time to time depending on a given set of conditions for each operation.

A great deal of detailed description has been given the lathe operation because it plays such a vital part in the preparation of quality rotary-cut veneer.

Most plants on the Pacific Coast employ the tray system in delivering green veneer from the lathe to the clipper, but our plant uses the reeling and unreeling system. As the green veneer comes from the lathe the "fish-tails" and "roundup", which come from the log while it is being made round, drop on to belt conveyors which carry them to the clipper. After the log has been made round, the end of the green veneer sheet is fastened to the reel by staple tacks. The speed of the reel is synchronized with the speed of the lathe which allows the veneer to be rolled up on the reel. When the reel is full it is pushed down to the green clipper where it is raised up on the unreeling machine for clipping.

There are several advantages in using the reeling system for pine. It gives the clipper operator much more time to do the job of grading because he is operating separately from the lathe. There is enough room to store a good two hours' run between the lathe and clipper. It takes less building space than the convential tray system in the ratio of approximately 60 feet to about 100 feet required for trays.

The face stock is removed from the log first at a given thickness. Then the log is dropped out of the lathe and set aside until later in the day when it is put back into the lathe and generally run to a heavier thickness than the face stock. This, incidentally, calls for a different knife bevel.

The green clipper operators, of which there are two, attempt to clip the heartwood from the sapwood as well as to make given grades by clipping out defects.

The veneer moves from the clippers to the green chain on conveyor belts where it is pulled by hand onto trucks according to species, thickness, drying segregations, widths, and lengths. These truck loads are then taken to the driers.

The drying process is a very important step in the manufacture of good veneer. A constant supply of steam is of paramount importance. The amount needed will vary according to each operation but generally speaking it takes from 150 to 200 pounds of steam on a high pressure line to do an adequate job of drying within reasonable time limits. Proper instruments, such as master recording controllers, steam pressure controllers to eliminate line surge, and recording tachometers which indicate and record the rate of drying for each run, expressed in minutes should be provided. Proper air distribution and circulation must be adhered to in order to get uniform drying. The actual feeding of the stock into the drier has a great effect on correct air flow. If the veneer is fed end to end and side by side it will give the air little opportunity to leak by and around the pieces, but will force it into the proper channels for correct and uniform drying.

Proper drying schedules must be set up for each species, thickness, segregation, size of drier and type of drier. In a large 16-section drier the temperatures must be controlled by zones, of which there are three.

Drying schedules on pine, at our plant, vary from 33 minutes for 1/6-inch ponderosa pine sap at 300° F. to 9½ minutes for $\frac{1}{16}$-inch ponderosa pine heart at 220° F. These schedules will dry veneer to 8 to 12 percent moisture content. Most plywood plants want their stock dried as low as 3 percent for hot-press gluing.

Proper maintenance is very important with respect to the driers. They should be thoroughly cleaned each week. Pitch accumulation, knots, slivers, and debris must be blown out with air and a thorough inspection given all working parts at each cleaning. With driers operating at from 300° to 400° F. accumulations of such debris as well as excessive grease must be removed frequently to avoid fires. Fires spell lost production and damaged equipment.

As the stock leaves the driers it falls upon a dry sorting belt where the graders mark it for grade and proper sorting. Some stock is on

grade as is, some has to be sent to the patchers to raise the grade, some to the clippers for further processing, and some to other graders who lay it up into panels for special orders.

The patching of lower grades to raise the grade has become an integral part of most plywood plant operations. There are three types of patches generally accepted for "single-line veneer". The "boat" patch is approximately 6½ inches long by 1⅝ inches wide at the widest part and shaped like a boat; the "cookie" patch is perfectly round with a diameter of 3¼ inches; the "Skoog" plug is also perfectly round but with a diameter of about 2½ inches. Both boat and cookie patches have a beveled edge to which glue is applied. Heat is used to set the patch firmly in place. The "Skoog" plug is merely a friction plug with a square edge and is held in place without any gluing. It is not satisfactory to use where single-ply veneer is to be transported any distance because it will fall out. It is intended for use in plants where the sheets are made into plywood.

The material from which patches are made should be high-grade face stock, heartwood preferred, straight, flat-grained and cut to uniform thickness. The patch-making equipment must be kept in perfect condition in order to make perfect joints. Most patches which are glued are set with urea-formaldehyde resin glues which are water resistant, and produce good tight fitting joints. The application of the glue to the patches is done by several methods, the two most common being by brush or by spray gun. It is quite exacting and must be done with a great deal of care. Too much glue will cause the patches to fit improperly and not enough will result in "starved" joints, which in turn allows the patch to fall out. Patches must not be cut too far ahead of their use because if they shrink they won't fit. The glue must not be applied too early or it will harden and then fail to set when heat is applied. The room temperature has much to do with the working life of glue. The more uniform the temperature of the room the better the gluing operation. Most patches are set with commercially designed "patch setters" which can be adjusted for glue-setting cycles according to stock thickness, species, room temperature, etc.

Splicing veneers edge to edge is becoming a vital operation in most plants also, in order to produce wide sheets from narrow, and to produce certain desired patterns that do not result from the natural growth in the log. The newly designed splicing machines for the making of high-grade face stock perform best on stock thinner than ⅛-inch, although they can be used with high-frequency current in such a manner that they will do a good job on thicker stock. The machine commonly used for this job has a traveling chain bed with an overhead heating arrangement and contains a "calrod" heating element that sets the glue while the veneer passes along on the chain bed.

The material to be glued is usually prepared at a jointer which may be either the traveling-head type or the traveling-bed type. The edges are all jointed perfectly at this machine by the use of sharp knives which are placed in a rotating head. In most cases the glue is applied at this machine by the use of either a rubber or metal roll passing over the smooth joints as they are made. The proper co-ordination of the jointer and splicer will make for good tight joints of uniform thickness.

Dry clipping of veneer varies considerably with each operation and with the type of orders to be filled. In most plywood plants the veneer is used ultimately to make plywood, so much of the clipping can be done green, but in a veneer plant such as ours the dry clipping becomes a major operation. Much of the high-grade face stock in ⅛-inch thickness goes into the making of veneers from which door stile and rail faces are made. These have to be sized to exact widths of 4⅞ inches, 5⅞ inches and other sizes.

Cutting thin sheets into such narrow widths is costly and slow but is necessary in order to recover the high grades from what would otherwise be less valuable stock containing various defects. After the widths are cut according to order it is necessary to cut the stock to exact length. This should be done on a well-designed veneer trim machine saw.

Specially designed gang rip saws also increase production of stile veneers from a given width of sheet. However, the stock must be picked and graded for this operation. The stock must not contain any defect that is not permissible in a stile or rail as the stock is actually

cut up "alive" and there is no opportunity to eliminate defects.

The cutting to length of rail type veneers is a slow and expensive task. Rail-type veneer is sold generally in short lengths from 16½ inches to 30 inches. A regular box-factory, California-type push cut-off saw does the job fast and as well as any. The saw operator can eliminate defects by cutting them out and still not slow up production due to inspection of stock.

Shipping practices for veneer vary a great deal with the type of order, the customer, and the method of transportation. Most customers want the high-grade face stock crated. Sliced stock is sold in crates from 6 inches to 12 inches wide, or if random width, up to 52 inches wide, where the veneer has been edge glued to 50-inch and 96-inch panels. Most stile veneers are packaged 50 pieces per bundle and gummed tape is used to tie the bundle. When large crates are desired the limit is generally 450 pounds to the crate. Lower grades are generally either loaded loose in the car or piled on lift truck pallets and strapped with a metal band. The scale is obtained either by piece tally or by measuring the pile and applying a formula that will give the square feet contained in the order. The bulk of the veneer is shipped in railroad cars, although, some does go by truck.

Slicing Method

The second part of this paper will have to do with the slicing operation through the green preparation since the dry stock is treated in the same manner as the rotary cut stock.

The transportation of stock to the slicer varies a great deal with the type and size of plant and whether the stock be soft or hardwood. At our plant the stock for the slicer is picked on the head rig in the sawmill. Clear pine flitches are saved from the log as the sawyer watches for suitable material. The clear flitches are all cut from the sapwood of the log and should be free of nearly all defects. They should be cut from 6 inches to 28 inches in width and 4 inches or over in thickness. It has been the practice to use only stock 16 feet in length. The Idaho white pine cants are also cut on the head rig and are cut from the heart of the log. They should contain only small, firm, red-type knots that result from live branches rather than black-type knots that result from cutting dead branches. These cants are generally 6 inches, 8 inches, 10 inches and 12 inches in width and thickness.

Both cants and flitches are transferred to the veneer plant, which is a distance of 1,500 feet from the sawmill, on a 30-inch wide rubber conveyor belt. As they arrive at the veneer plant they pass down an inclined chain through a dip tank. The tank contains a chemical solution which prevents blue stain from developing in the material in storage. The cants are removed from the dip tank by an air-hoist and piled in lift truck units. As they are piled in these units they are scaled and the amount recorded in board feet. After the loads are scaled they are moved to a storage room. Added moisture keeps the stock from season checking before it is used.

In order to do a good job of slicing it is necessary to give the cants and flitches a good steaming or soaking to soften the wood. Three large steam boxes are used for this purpose. The boxes are fed with live steam which has been passed through water. A master controlling instrument maintains a constant temperature. Knotty Idaho white pine cants are steamed for 15 hours at 138° F. The clear pine flitches are steamed for 15 hours at 132° F. The stock is placed in the boxes in lift truck units. After it is taken out the clear flitches which contain bark on the edges, must be placed on a "spudding" table where the bark is removed before the flitch is placed in the slicer. The cants have no bark on the edges, as they are cut from the heart of the log.

The "slicer" machine itself is a precision instrument and must be maintained and set up as carefully as the lathe. The slicer operator should be a man who has a love for machinery and a world of patience. The machines vary with the make, model, and year but basically they are all operated on the same principle.

The relationships between the nosebar, knife, and flitch table are the key points in cutting good, uniform veneer. The flitch or cant should be loaded into the slicer so that it is on an angle with respect to the knife. This gives a shearing action and results in better cut stock.

The stock should be cleaned thoroughly to eliminate all dirt, fine sand, grit, or other foreign materials that dull the knife. It is more difficult to "fit up" a slicer than a lathe. Our slicer has a 17-foot knife as compared to the 8-foot knife on the lathe. Most of the stock at our plant is cut to 1/28-inch, 1/20-inch, 1/16-inch, or 1/8-inch thickness. However, slicing operations have been known to slice stock as thin as 1/300-inch in fine hardwoods. When cutting high-grade, fine hardwoods the stock is sold by taking samples from each flitch which means that the veneer from each flitch must be kept to itself. In slicing pines this is not necessary so the stock is placed on a truck after being cut into 8-foot lengths. Clear flitches are sliced from the face side to the back to leave the "dog board" on the back. Knotty Idaho white pine is sliced to the center of the cant. Then the piece is turned over and sliced to the center again. In this way the dog board is taken out of the center. This is done because of the way the grain runs in the heartwood.

From the slicer the stock goes to the drier and is processed in the same manner as the rotary cut stock. The sliced knotty-pine is dried and if the customer wants the material edge glued into face sheets a grader matches the pattern by using veneer from different cants in order to obtain a good distribution of the pine knots.

In conclusion, this is a new industry with respect to pine, but experience will teach what will finally be considered as practices which are good and how to avoid those which do not produce the best possible balance in operating techniques.

Literature Reference

E. H. Merritt, 1949. Report on production of single ply rotary veneer at Potlatch Forests, Inc., Lewiston, Idaho.

Discussion

Mr. J. H. Grant, Jr. (Burritt Lumber Sales Company, Inc.): What types of glue are used for assembly and edge gluing?

Mr. Reinmuth: Urea formaldehyde is used.

Mr. R. C. Fraunberger (Philco Corp.): Is pine easier to cut than Douglas fir?

Mr. Reinmuth: No, I don't believe pine is as easy to cut as Douglas fir.

Mr. O. H. Schrader (Douglas Fir Plywood Association): What can be done about knot problems in white pine?

Mr. Reinmuth: Cutting logs while they are fresh will help. Sometimes knots are bored out on the lathe.

Mr. C. Reckers (Washington Veneer): Have you encountered any trouble on drying pine veneer? White pine obtained west of the Cascades seems very difficult to dry, particularly around the knots. It is necessary to dry the stock on a fir sap veneer schedule with some spots up to 25% moisture content still showing up around the knots which of course is serious with phenolic resin gluing where moisture contents below 5% are desirable. Have you encountered similar drying problems?

Mr. Reinmuth: We have not experienced much trouble. My advice is, take your time, use lower temperature, and have the necessary instruments for control.

Mr. E. Stivers (Package Research Laboratory): How does sliced veneer compare with rotary cut veneer in yield?

Mr. Reinmuth: They can't be compared. Stock for slices is selected on the head rig in the mill and recovery is different due to method of manufacture.

Mr. H. W. J. Peck (Vancouver, B. C.): Will you please describe the type of instrumental control used on your driers?

Mr. Reinmuth: We use standard Moore controls, master controllers, steam pressure controllers and recording tachometers.

Mr. Schrader: How is your raw material supply situation?

Mr. Reinmuth: We get lot of sawlogs, but we have to look for our supply. Good peelers are scarce and difficult to find.

Mr. A. G. Idso (Puget Sound Plywood Inc.): Do you use a tilting head on your lathe, or do you use the sliding head? What is the chief factor contributing to thick and thin veneer?

Mr. Reinmuth: We use the tilting head. Many factors affect the thickness of veneer, among them are the lack of precision in "setting up", the lathe blade in relationship to the roller pressure bar, improper maintenance of lathe, poor work in filing room, dull blades, poor logs etc.

FOREST PRODUCTS RESEARCH SOCIETY

Gluing Operations—Industry Trends

Donald V. Redfern

Technical Director, American-Marietta Company, Seattle, Washington

The paper covers general trends in the use of glues by the Douglas fir plywood industry from 1942 through 1949.

A comparison of hot-pressing and cold-pressing is made, including the merits of both. Adhesives for these two pressing operations are described and their good and bad points discussed.

Present trends and probable future developments on Douglas fir plywood glues are discussed.

Introduction

THE Pacific Northwest plywood industry, consisting of roughly 75 mills, produces a staggering total of over two billion square feet of plywood per year (on a 3/8-inch basis) at present production levels. It is obvious that the amount of glue consumed in bonding this plywood is large.

Consumption of glue for 1949 was roughly 30,000 tons (60,000,000 pounds), which represents a business of approximately five million dollars. The major producers of this volume are located in the Pacific Northwest and have skilled staffs to serve the customer. Because of the special nature of the business, successful adhesive producers are those who have applied themselves diligently to customer needs by the development of new adhesives and by furnishing technical advice in their application.

There are very few producing industries that have seen costs decline in any phase of their operation during the past ten years. However, this is an accomplished fact in the use of synthetic resins for the bonding of plywood. Glueline costs dropped sharply during this time and at the present are rougly one third of what they were when phenolic resins were first used for the manufacture of exterior plywood.

Because of the variables encountered in gluing Douglas fir into plywood, the adhesive industry has placed special emphasis on quality control in an effort to maintain uniformity of its products.

Logs, labor, and glue are necessary to produce the finished plywood panel, none being sufficient without the others. This has resulted in an ever-increasing awareness, on the part of supplier and consumer alike, of the necessity for close supervision of the gluing operation. The best prepared veneers in the world and the most skilled workmen obtainable cannot produce good plywood without the proper adhesive and the correct procedure for its use. Some current methods and equipment are good but there is room for improvement. The following discussion will outline the procedures used in the production of plywood from veneers.

Mixing the Adhesive

The glue is usually prepared for use in a mixer located on a raised platform in the glue loft. The mixer has blades that scrape or nearly scrape its sides and bottom in order to facilitate more thorough mixing. Located above and beside the mixer is a water-measuring tank with facilities for heating the water. Below the mixer and usually to one side at floor level is a storage tank for the finished glue.

In order to provide for the widest latitude in the mixing operation, the glue mixer is jacketed for both water and steam and the water tank has a live steam inlet in order to heat the water to the desired temperature.

The general layout of a conventional mixing system is given in Fig. 1.

The evolution of mixing equipment has been slow but the trend is to design equipment to permit a wider latitude in formulating glue mixes. Where phenolic resins are used for both interior and exterior plywood, the only change in glue mixing may be a further extension of the resin with inert or proteinaceous materials, for inferior grades.

Protein adhesives are quite thixotropic and because of this, trouble does occur in getting these glues to flow by gravity from the storage tank to the spreader. This condition is frequently aggravated by small glue distribution pipes leading to the spreader. However, it

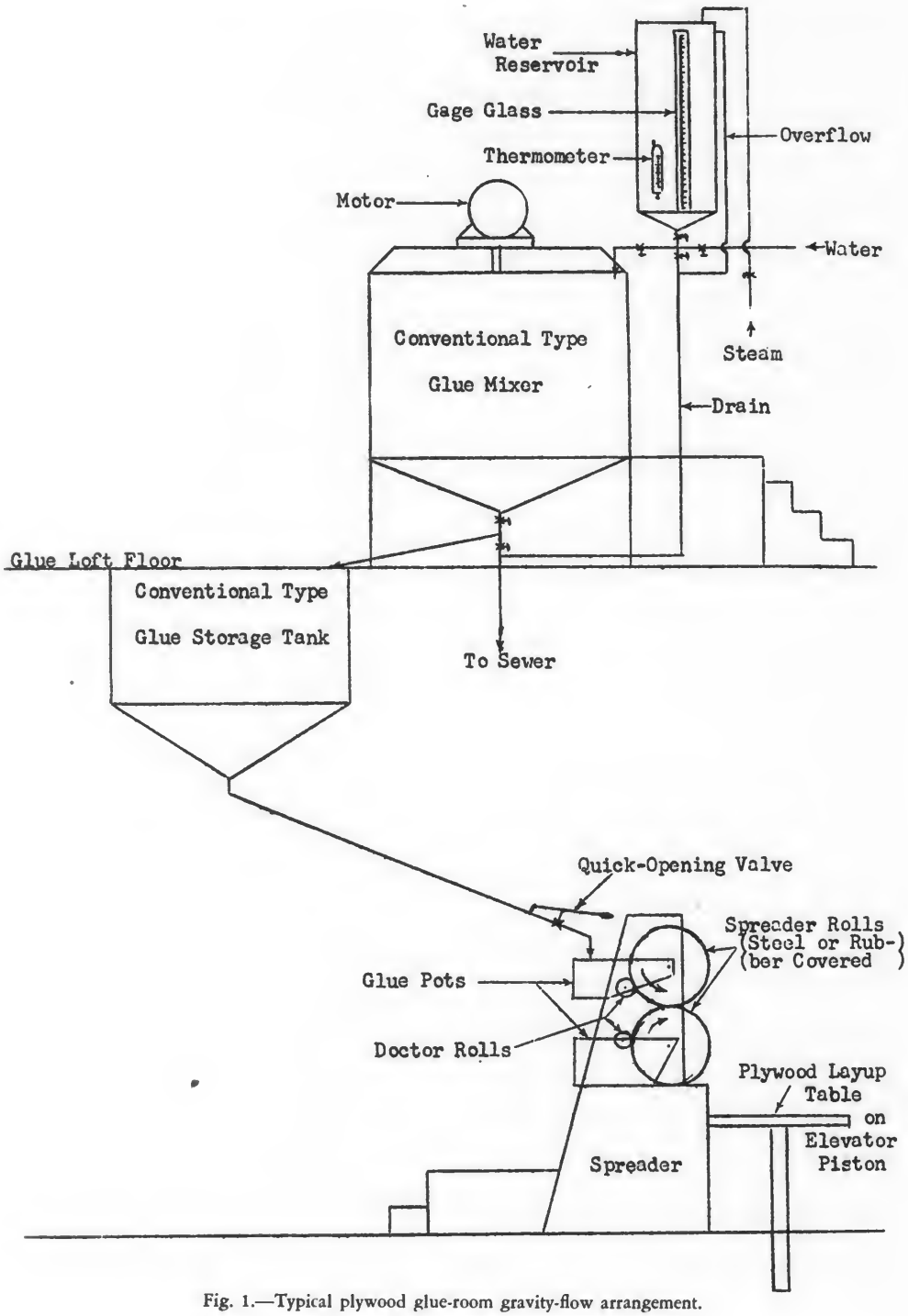


Fig. 1.—Typical plywood glue-room gravity-flow arrangement.

seems that those chemical properties that cause thixotropy in protein adhesives also are desirable and a measure of glue quality.

Based on this reasoning, a system of recirculation has been developed especially for cold-press protein adhesives whereby the glue in the storage pot is kept in circulation. This prevents the material from gelling and allows the use of adhesives with greater thixotropic tendencies than could be handled with conventional equipment.

The process is essentially the recirculation, by means of a gear pump, of part of the glue in the storage tank. The glue is drawn from the bottom and is pumped back into the top of the storage tank (Fig. 2). A conical baffle disperses the returned glue.

Spreading the Adhesive

After mixing, the glue is spread on both sides of the plywood core or crossbands by large rolls running in a bath of the adhesive. The spread of the adhesive is regulated by smaller steel doctor rolls and by the nip between the spreader rolls (Fig. 2). The spreader rolls are either steel or rubber coated, depending upon the type of adhesive and the spread requirements. Steel rolls normally are used for protein-glued, cold-press plywood when heavy spreads are required. Rubber-coated rolls are used primarily in hot-press operations for both the synthetic resin and protein formulations.

The rolls have groovings of various types and depths and sizes according to the recommendations of the various glue suppliers and users.

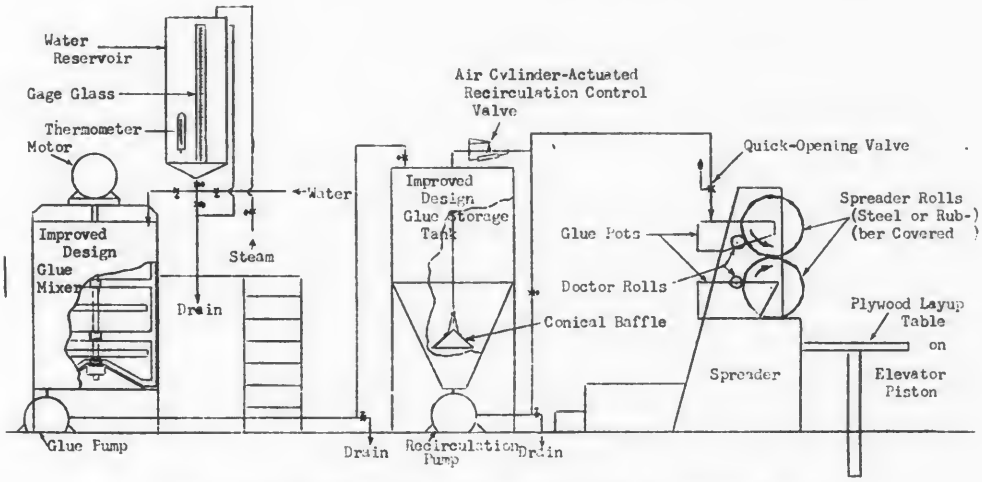


Fig. 2.—Typical one-floor plywood glue room using recirculation system.

The system, when installed, has met with good success and has improved results in the gluing operation. In the past it has been necessary at times to add extra water to the protein glue mix in order to obviate the thixotropic tendency. With the recirculating system, this need not be done for the glue is kept fluid by the constant recirculation.

Improvements in glue mixing equipment can be made by closer cooperation between the manufacturers of glue mixers and adhesive suppliers.

Spreaders

The conventional roller spreader used in the plywood industry on the West Coast, in the writer's opinion, is not satisfactory for proper spreading. If we could assume that all core stock put through the spreader was of uniform thickness and perfectly smooth, then the amount of glue transferred to the core would always be the same. However, this is not the case, since core stock, because of the very nature of the log and the method of removal of veneer from the log, produces an unevenly-surfaced

material. Surface irregularities are produced in the peeling operation by changes in lathe speed and pressure on the roller bar. Knots, especially in Douglas fir have a tendency to fall out. All these things produce a final product which tends to pick up glue from the spreader rolls in uneven quantities over the surface. The gluing job could well be done by a method that would transfer to the stock a uniform thickness of glue over the surface in amounts determined to be the best. This problem is one of prime importance and is one in which, economically speaking, the industry should be very interested. The plywood panel, especially Exterior, is no better than its weakest link and in some cases this weakest link is simply the uneven spread of adhesive caused by one or more of the variables just listed.

Pressing

There are two distinct types of pressing operations, hot- and cold-press. Production is divided quite evenly between these two methods.

Cold Press

By far the older method is cold pressing. In this process the bundles of veneer are placed in a press with thick caul boards on the top and bottom and with interlayers of thinner cauls. Pressure is applied at room temperature. The bundles formerly were clamped in irons before removal from the press and were allowed to stand from four hours to overnight before the clamps were removed. Now, however, the use of irons and clamps has been superseded by the patented procedure known as the "No-Clamp Process." This means exactly what it says. The panels are placed in the press as if they were to be clamped and pressure is maintained for a given time depending on conditions. Special "No-Clamp" protein glues are used. After 15 to 25 minutes the pressure is released and the panels are removed to a storage area. This practice eliminates the use of the expensive and cumbersome clamps and irons used formerly. The present large volume production of cold-press plywood is accomplished almost completely with protein adhesives. The cold press process is confined to the production of Interior Type plywood, thus restricting the final use characteristics of the finished panel.

Hot Press

The second of the two modern methods of plywood manufacture is hot pressing. The wide latitude of glue-line characteristics which may be added to plywood by the use of the hot press, has resulted in a large scale installation of this manufacturing equipment. Temperatures in the pressing operation vary with the type of adhesive and production needs, the range being from 220° to 315° F.

It is the practice, at times, to press panels less than $\frac{9}{16}$-inch in thickness two or more per opening. However, this has a tendency to produce panels that are subject to warping due to the variation in temperature and moisture gradient. The panels require careful stacking and equalizing to obviate this tendency to warp. There has been a recent tendency to press all constructions with one panel to the opening. It has been argued that pressing the panels two per opening kept production higher, but this argument does not hold true in all cases. The fact is that heat transfer from the platens to the glue line is inversely proportional to the square of the distance from the platen to the glue line. Hence, when the thickness is doubled by placing two panels in an opening, the press time is three to four times longer than that required for one panel per opening. Advantages of operating with one panel per opening are:

(1) A flatter panel is produced.
(2) The time in the press is shorter, thus decreasing the chance of harming the surface of the panels by overheating.
(3) The effect of surface defects is limited to the panel in which they occur.
(4) Glue lines are maintained at the desired temperature for a longer time.
(5) Production may be higher due to reduced pressing cycles required.
(6) The open-assembly time before pressing is shorter due to the pressing of half as many panels at a time. This lessens the tendency for dry-out or precure of the glue before pressing.

Adjuncts to the pressing operation that have aided in better plywood production are automatic loaders and unloaders. An innovation in loaders is one that operates on a moveable carriage to and from the press, reducing a tend-

ency for glue-line precure due to the heat radiating from the platens, especially if the panels lie in the loader any length of time before entering the press.

Inherently there are advantages and disadvantages to both the cold- and hot-press. A tabulation of some of these follows:

increase continued rapidly to 1945. This increase occurred in the face of lowered production for the industry because of wartime shortages of logs. The increase occurred because of the heavy demand for exterior plywood for our numerous war uses such as for military boats and war housing; both military and civilian.

Cold Press

Advantages

1. Low initial investment.
2. Allows wider latitude in veneer condition such as roughness, knots, etc.
3. Veneer-drier production is higher because veneer may be at a higher moisture content —5 to 10 percent.

Disadvantages

1. Restricted to Interior-Type plywood.
2. Glue-line cost is higher than with the same type of panel hot pressed, due to higher spread necessary.
3. Panel weight is somewhat higher with resultant higher freight costs.
4. Pressing times are longer.
5. Longer time must elapse before the panels can be trimmed, sanded, shipped.

Hot Press

Advantages

1. Wider latitude in glue line performance allowing the production of both Interior and Exterior plywood.
2. Glue line cost is lower than cold press due to use of lower spreads.
3. Panel weight is less due to drier veneers.
4. Pressing times are much shorter.
5. Panels can be trimmed, sanded and shipped sooner.

Disadvantages

1. High initial investment.
2. Veneers must be dried to a moisture content of at least 3 to 5 percent to prevent blisters.
3. Panels are dangerously dried out and in some cases need rehumidification to prevent splits and checks.
4. Veneers must be more carefully sorted and prepared.

Industry Trends in Adhesive Use

Before discussing industry trends in the use of adhesives, it is proper to review production figures of the past few years (Table 1). Table 1 is based on tabulated data obtained from *Facts For Industry, Softwood Plywood,* U. S. Department of Commerce.

From these data it is readily seen that in 1942 the use of phenolic resins for the manufacture of Exterior Grade Douglas fir plywood was just getting well under way and that this increase continued rapidly to 1945. This increase occurred in the face of lowered production for the industry because of wartime shortages of logs. The increase occurred because of the heavy demand for exterior plywood for our numerous war uses such as for military boats and war housing; both military and civilian.

The Douglas Fir Plywood Association has played a great part in increasing awareness of the structural advantages of plywood and with the development of Exterior Grade plywood many new markets were opened to the Douglas fir plywood industry.

The figures show that with raw materials available the production of Interior as well as Exterior plywood has increased since the end of the war. This indicates that Interior plywood has a definite field of use.

TABLE 1

Year	Total Plywood Production M. sq. ft.	Exterior Grade			Interior Grade		
		M. sq. ft.	Percent of Total	Lbs. of Resin Used	M. sq. ft.	Percent of Total	Lbs. of Protein Glue Used
1942	1, 840, 231	270, 630	14.7	17, 262, 000	1, 569, 601	85.3	37, 380, 000
1943	1, 495, 170	304, 202	20.3	19, 764, 000	1, 190, 968	79.7	26, 086, 000
1944	1, 484, 889	367, 728	24.7	23, 067, 000	1, 117, 161	75.3	27, 879, 000
1945	1, 222, 382	364, 063	30.0	19, 393, 000	858, 319	70.0	22, 473, 000
1946	1, 436, 065	438, 036	30.7	24, 743, 000	998, 029	69.3	23, 817, 000
1947	1, 700, 446	587, 066	34.6	36, 054, 000	1, 113, 380	65.4	24, 728, 000
1948	1, 953, 883	619, 869	31.7	40, 053, 000	1, 334, 014	68.3	30, 285, 000
1949	1, 864, 877	382, 430	21.3	30, 590, 000	1, 467, 143	78.7	31, 775, 000

For one thing, there has been an increase in the number of plywood mills from 1944 to 1949. Most of these new installations, because of limited capital, have started by cold pressing their plywood. The history of these new installations shows a trend toward the installation of hot presses as soon as sufficient capital is available.

Another factor is the installation of cold presses in hot press mills to increase production and to use veneers that are unsuitable for hot pressing.

In order to improve performance, the DFPA requirements for acceptance of Interior Grade has been raised. This was accomplished by the elimination of the two-cycle test and the use of the ten-cycle test as a criterion of acceptance.

A cycle consists of soaking a 6-inch by 6-inch test square of plywood in water for four hours at room temperature followed by 20 hours of drying at a temperature no higher than 100° F. This change in requirements virtually eliminated the straight soya-meal glue from the hot press technique because of its inability to pass the test. The major cause of failure is the low glue spread for hot pressing. Cold press soya-meal adhesives give good performance in the new Interior Grade test.

A little known, but quite noticeable, change in adhesives is the change over from hydraulic and expeller soy meals to solvent-extracted meal. This changeover has been forced on the adhesive industry because of the economics of meal and soy-oil production. However, it has been a blessing in disguise, for the solvent meals produce better adhesives once the fundamental problems of their different use characteristics were solved.

Protein Adhesives vs. Synthetic Resin Formulations

Because of the inability of straight soy meal glues to pass the new interior ten-cycle test when hot pressed, the industry has gone largely to two specific types of adhesive for this purpose.

Protein

The first and by far the older is the fortified protein type. This adhesive is usually a combination of soluble blood and soy meal. This fortified glue has certain advantages over other adhesives used for this purpose but there is much difference of opinion regarding performance as compared to extended-resin formulations.

Advantages and disadvantages of this type of adhesive are as follows:

Advantages

1. Pressing times and temperature are lower than those for resin adhesives.
2. It gives a better spread pattern partly due to heavier glue spread.
3. Tendency for blows is less.
4. Glue will stand a higher limit of moisture in the veneers.
5. The heavier thixotropic film resists wipes better than resin.
6. Less rigorous drying required and hence less effect from this on wood; e.g., warp and checking.

Disadvantages

1. Poorer spreading characteristics.
2. Bond is water resistant but does not have the waterproofness of an equivalent resin glue.
3. Protein glues are susceptible to bacterial and fungus attack under proper conditions of moisture and humidity.
4. Mixing more complicated in general.

Synthetic Resin Formulations

Because of the success of phenolic resin in making hot-press exterior plywood it was natural to extend the use of these resins to produce Interior Type glue bonds.

The approaches have been varied but essentially they consist of an increased amount of extender and water. Attempts have been made to incorporate soluble blood in order to lower the time-temperature pressing requirements.

The Plywood Research Foundation developed a novel formulation which consists of reclaimed motor oil in an emulsion with the standard phenolic resins on the market, water, and walnut-shell flour extender. Claims are that this extension is economical and that the oil provides a means of preventing glue lines from

drying out both during open assembly and the hot-pressing operations. The process is patented by the Foundation but is available for license at a nominal fee.

That the production of Interior plywood with resin glues has "caught on" is evidenced by the fact that roughly 6,000,000 pounds of resin were used for Interior Grade plywood in 1949.

Tabulated below are listed some of the advantages and disadvantages of this type of formulation.

Advantages

1. Glue line bond, if properly made, is reasonably waterproof.
2. Susceptibility to fungus and bacterial action is reduced.
3. Permissible open assembly time is longer.
4. Ease of handling of resins in liquid storage.
5. Ease of mixing.

Disadvantages

1. Pressing times and temperatures are higher than for protein adhesives.
2. Spread pattern is poorer than for protein glues due to lower spreads especially on rough stock.
3. Blows will occur more readily.

Veneer Supply

It is a known fact that the declining quality of logs is becoming a serious problem. The days of ideal peeler logs are past. However, this problem can be alleviated to a reasonable extent by a better understanding of log types, and the type, thickness and treatment of the veneer to be cut from each log type.

An entire study can be made of the effect of handling procedures with the express purpose of improving the gluability of the final assembly. The term gluability is used here to cover the unknown or at least little understood factors that affect the final glue bonds.

Some of these factors are:

(1) Log quality and location in the tree.
(2) Locale where the log was cut.
(3) Thickness of the veneer cut.
(4) Type of lathe and lathe setting.
(5) Sorting of the veneers for drying.
(6) Drying cycle.
(7) Sorting of the veneers after drying.
(8) Veneer patching.
(9) Method of edge gluing the veneers.
(10) Handling of the veneers during spreading and pressing cycles.

It has been found that Douglas fir from certain sections of Oregon and Northern California is denser than our ordinary coast Douglas fir. This apparently is due to conditions of growth peculiar to the areas involved.

The gluing operation and adhesive efficiency must be such that the glue will bond both to the springwood and summerwood. Moisture absorption rates from the glue line vary in these types of wood. It is apparent from cursory studies made that veneer from logs with a higher density or a higher percentage of summerwood is harder to glue than veneer from logs with a normal percentage of summerwood.

This problem is accentuated by the surface condition of the veneers, which is directly a result of the handling procedure from the lathe to the final assembly.

A whole field for investigation is open here for better adhesive performance. The problem can be attacked in two ways,

(1) Improvements in adhesives.
(2) Improvements in gluability of veneers.

The adhesive manufacturers are well aware of the problem and have spent considerable time and research in adhesive improvements. However, it appears that one of the most fertile fields for improvement lies in a more careful survey and understanding of veneer gluability.

There is evidence to show that the temperature to which veneer is brought in drying has a very marked affect on the glue bond; apparently the higher the temperature the poorer the specific adhesive qualities.

This whole field of the relationship of veneer quality and type to glue-bond quality deserves much added study.

There is a challenge here to the industry as a whole; both the glue supplier and plywood manufacturer. Cooperation in learning the factors that control good gluing and an implementation of these factors must be made in order to insure the final customer—the consuming public—the quality he desires.

Conclusions

In review of the foregoing, it appears that trends in gluing in the plywood industry are definitely toward a better understanding of the problems involved. Coupled with this is earnest effort on the part of all concerned to see that these problems, as they are solved, are implemented with proper methods.

New developments in adhesives have been along the lines of improvement in basic raw materials and methods as far as protein glues are concerned and a more efficient use of the resins in synthetic resin formulations.

Equipment for mixing and spreading of adhesives is being improved slowly but there is a basic fault in the method of applying the adhesive by conventional glue spreaders.

There is an opportunity to more economically use the present adhesives assuming a more thorough understanding of the gluing problem. Good practice in the industry coupled with more and better quality control can save dollars and cents in glue line costs. A few of the factors to be watched are:

(1) Accurate glue mixing practices.
(2) Good and/or improved glue spreading techniques.
(3) Careful control of veneers coming to the spreader—presorting if possible into smooth and rough categories.

Protein glues will not be supplanted by the synthetic resin adhesives. Basic use requirements of both types will keep them on a healthy competitive basis. Research will tend more toward overcoming the basic defects of both types to the advantage of the customer.

Cooperation among all concerned is the keynote of the continued economic use of plywood by the most important man in the world—the plywood customer.

Discussion

Dr. Frank Kaufert (School of Forestry, University of Minnesota): Since present spreads are more or less adjusted to take care of rough veneers, is it practical to sort veneers in the plant into smooth and rough grades—thus making reduced spreads possible on smooth veneers?

Mr. Jack Rushton (Weyerhaeuser Timber Co.): I can't give an answer right off. You would have to balance labor cost of segregation against cost of glue savings.

Mr. N. S. Perkins (Douglas Fir Plywood Assn.): We used to have eight veneer grades; now we have four. This was hailed as a step in right direction. The industry is not in favor of segregation of grades.

Mr. A. J. Norton (Consulting Chemist): If you can break even on cost, increase in quality would be worthwhile.

Mr. Harry Snell (Celanese Corp. of America): Does the hot press affect the surface characteristics of the wood?

Mr. Redfern: There seems to be definite information showing that it does; especially surface cracks and checks.

Mr. J. F. Hamilton (Perkins Glue Co.): Has any method for screening poor bonds by the newer electronic devices been found satisfactory?

Mr. Perkins: The Douglas Fir Plywood Association did some work along this line with an eastern concern to detect blisters with supersonic sound. It was not satisfactory, because it picked up veneer defects that were not blisters. We have since developed a method of detecting blisters with lights, that seems to be proving quite effective.

Future of Plastic Surfaced Douglas Fir Plywood

John D. Ritchie

Allied Products Director, Douglas Fir Plywood Association, Tacoma, Washington

Plastic surfaced Douglas fir plywood, which has been produced on a limited basis by the fir plywood industry, is beginning to gain in significance. Better utilization of raw material, a more attractive return for production dollars spent and the need for a special product in a competitive market have influenced this industry toward strongly considering this type of material in their long range planning.

THE "Future of Plastic Surfaced Douglas Fir Plywood" is a big subject. Percentage wise the volume produced at present is small, but markets are expanding steadily. The potential capacity of the fir plywood mills to manufacture this type of product is tremendous, so that, with the development of new uses and new markets plus other considerations to be discussed later in this paper, it seems inevitable that the "overlays" will play a significant part in the future of the fir plywood industry.

The subject is not a new one and it may seem odd that we are still talking about the future of plastic surfaced Douglas fir plywood when the material actually has been manufactured since the early days of the war. Many millions of feet have been made, but the real volume, according to the standards of the fir plywood manufacturer, is still in the future.

The fact that the production of plastic surfaced plywood has not expanded to a greater extent during the recent years is due primarily to a steady demand for all of the standard Douglas fir plywood that could be manufactured. Under such conditions, special products, which require more attention and particularly more press capacity, develop rather slowly. Some material has been made right along, however. It has been a good breaking-in period, so that the time has not been lost.

Overlaid fir plywood as a new product already has been covered in previous papers and magazine articles. For this reason, this discussion will be devoted primarily to demonstrating how these products fit into the over-all industry picture. Conditions in the fir plywood industry change as they do in other industries; some gradually, some rapidly and unexpectedly. Therefore, if we examine these products in the light of present circumstances, perhaps we can keep our paper current and avoid repeating what has oft been said before.

To begin with, there are two requirements that any new product must meet if it is to have a future. First—there must be a demand for it. Second—it must be economical enough to produce so that it can be sold at an acceptable price and return a reasonable profit.

Sometimes the demand comes first; other times the product. In the case of plastic surfaced plywood, it has been established that it can be produced economically. Now we are beginning to give it the necessary push to build a market to receive it in volume and thus provide the two requirements for a sound future.

Materials Currently Produced

Before discussing the overlaid fir plywoods currently produced it should be emphasized that at this stage in their development, no manufacturer is entirely set on the markets which he proposes to seek out, nor is he entirely certain that his present overlay is exactly that which he will wish to make in the final analysis. Therefore, while I am obliged to speak of types of overlay, I do not wish to leave the impression that they are in any way fixed or without possibility of adjustment.

There are three main types of plastic surfaced Douglas fir plywood produced now. Each has its individual characteristics, but they all have certain things in common. They are manufactured in standard plywood sizes and, with one exception, standard plywood thicknesses. They can all be manufactured on present equipment.

One type provides an opaque surface. It is a solid color, usually reddish brown, but a limited number of panels have been made in lighter

shades. This material is intended to blank out the underlying veneer grain and present a uniform, smooth surface. It is a phenolic resin impregnated paper hot pressed to exterior type Douglas fir plywood. It is tough, durable, and an excellent paint base.

The second product is manufactured in a similar manner, but it provides a translucent surface that allows the underlying grain pattern to show through as a distinctive appearance characteristic. It is usually natural in color. It also may be painted, but since it has a very hard abrasion-resistant surface, it is most often used in locations where no finish is required.

Product number three is quite different from the other two. Rather than a resin-impregnated overlay, this material is made up of a phenolic resin and wood-fiber-mix hot pressed to one side only of an exterior panel. It is wood color and provides a good paint base. To date it is made only in the 3/8-inch thickness.

If you examine samples of these products, you will note that they are attractive in appearance, painted or unpainted, but that they are different from decorative laminates. The fir plywood industry is geared to large production. Their specialty items can be produced in large quantities on present fir plywood manufacturing equipment. They are not low-volume, high-return items.

Overlays Improve Log Recovery

You may be acquainted with the tremendous expansion of the fir plywood industry during the past eleven years. Production has increased from six hundred fifty million square feet in 1938 to two billion square feet in 1948 and 1949. The year 1950 promises to be the highest yet. The number of manufacturing units has increased from 18 in 1938 to 54 at present. Hence, the demand for peeler logs has increased at a corresponding rate. Log procurement has generally become the number one problem. In order to protect their source of raw material, many operators have acquired their own logging operations.

Not only has the demand for peeler logs increased tremendously, but the available supply is not of the clear, old-growth type used in the past. As a result, the plywood industry has had to do more patching, more plugging, more shimming, and more jointing of narrow strips than ever before. The industry has increased the percentage of 5-ply and "one-side" panels produced in order to spread the top quality face veneers as far as possible. The commercial standards are kept current so that they remain in line with the quality of veneer available.

Plastic surfaced plywood has a very definite place in this picture. It is an effective means of upgrading veneers into premium, finished products. This does not mean disguising low quality material. With overlay surfaces, veneers can be repaired more rapidly and economically than would be possible if the veneers were exposed. Actually all veneer for plastic surfaced panels manufactured today must meet the standard for exterior type Douglas fir plywood. So far all overlaid panels exceed that standard.

Overlays a Factor in Plywood Production Costs

In addition to improving log recovery, plastic overlaid panels, as they are manufactured concurrently with fir plywood, can play an important part in meeting high production costs, particularly in regard to logs, labor, and overhead.

Log prices have risen steadily during the past ten years and, with a decreasing supply, it is concluded that they will remain high. In addition, there is the ever increasing expense of transportation. Logs must be moved farther from the forest to the plants.

Hourly wages are at an all time high. These also must be considered permanent. In addition to hourly wages, there is increased cost due to the added manpower required to make plywood from the raw material available today.

Overhead has in the past few years taken all the usual jumps plus increases which go along with the extra manpower and machinery necessary under present circumstances.

In view of the foregoing, it has been said that the only out for the industry is to improve on equipment and to keep a constant vigil on efficiency of manufacture. This is correct as far as it goes, but there is another answer—that is, to produce some special product which employs generally these same raw materials, labor, and overhead, but which will bring in a higher dollar return per unit.

This is where overlays fit in. Certainly there are some added costs in connection with these specialty products. There is the cost of the paper, the resin, and the longer pressing schedules which may mean reduced production. In addition, numerous small expenses are connected with the manufacture of a premium quality item. Yet, it has been proved (with these things considered) that such special products can be produced to advantage.

Thus it can be shown that the manufacture of plastic-surfaced Douglas fir plywood can be fitted into the production pattern of this industry with the result that a more economical use can be made of the logs, and, with comparable production costs, a high quality product can be manufactured which will bring a greater dollar return.

Overlays Complete the Marketing Program

Now, from the sales standpoint, I believe it can be shown that overlays can play a significant part in a well rounded marketing program. It already has been stated that a decision as to whether or not to manufacture such special products depends primarily on demand—actual or potential. It depends likewise on what the demand is for the bread and butter item, Douglas fir plywood; and on what the competitive situation may be in regard to Douglas fir plywood. To illustrate—may I remind you that the fir plywood industry, with all its increased capacity, operated at full tilt for 10 years up through most of 1948. The shortage of plywood was acute; order files were full without exception, and volume production was the prime consideration. Under such conditions, specialties necessarily took a back seat.

Came the turn—and we found ourselves like many other industries in a strenuous competitive situation. We are over the first shock and today the volume of business is excellent, but the industry is now keenly aware of the need for a vigorous and continuing sales program. A long range viewpoint is being taken regardless of the fact that the need for developing immediate outlets is not present.

These are the circumstances best suited for such new developments as the plastic surfaced panels. First—because top efficiency in production replaces top volume as the number one goal. There is a place, therefore, in the manufacturing schedule for specialties. Second—because it is advantageous in a highly competitive market to have a "lead item"; a specialty which is not manufactured by everyone else. It will bring a greater dollar return. It can be an entering wedge and many times will carry the primary product along with it. Third—since it is a premium specialty and not manufactured by all of the producers of regular Douglas fir plywood, it may have a stabilizing influence on the market generally. It need not be subjected to the sometimes erratic ups and downs of plywood and lumber.

Since demand is the number one consideration in the last analysis, let us examine for a moment what demands exist at present and what potential demands may be expected in the future. In times like these, one might easily be led astray by apparent enthusiasm for new products which, over the long pull, might not continue. When the regularly produced material is difficult to obtain, a certain amount of demand for specialties builds up because they may be more readily available. Thus a false situation is created because the premium products may be put to uses which normally would not make sense. If our mills were willing to promise today that overlaid panels could be delivered promptly, I have no doubt that they could stimulate a tremendous interest in the material on that basis alone. This approach has been rejected. Actually, production of plastic surfaced panels is limited substantially so that the bread and butter item can be produced in volume.

There is a very real demand for these products at present which I am convinced is based on the qualities that the materials offer and the promotion and advertising which has been put behind them so far. It is not a result of a temporary plywood shortage.

Concrete Forms Expanding Market

Concrete form work is perhaps the greatest single outlet. Overlays do a superior job in providing a smooth, "fin-free" concrete surface. They can be reused many times so that they are economical. They strip easily, clean readily, and will stand a great deal of abuse. Where a smooth architectural type of concrete is required and it is possible to reuse the panels again and again, they are ideally suited.

Perhaps the best illustrations of this type of use are some of the huge apartment house jobs throughout the country. Outstanding among these is the giant Parklabrea project in Los Angeles. Here eighteen apartment house buildings each thirteen stories high plus one-story garages are of concrete construction. Concrete forms required 3,000,000 sq. ft. of Douglas fir plywood of which 750,000 were plastic surfaced. All the exterior of the buildings and interior ceilings were formed against plastic to supply the smoothest surface possible. The ceilings will be painted as is, with a minimum of further preparation. The Parkway Apartments, located just outside of Newark, New Jersey, is another example. The well known Gowanus, Woodside, Jacob Riis, and Waldon Terrace projects are excellent demonstrations in and around New York City. This is a big market and indications are that it will continue to increase.

Other Uses

There are numerous other applications such as box cars, refrigerator cars, truck bodies, trailers, walk-in refrigerators, cabinets, table tops, marine uses, toys, cut-outs, exterior siding, store fixtures,—even flooring. These are demonstrated uses, but they have not yet been developed to any significant extent. They represent tremendous potential markets.

Consider siding material for example No real emphasis has been placed on the use of overlays for this purpose, yet it can be advocated for a lot of very good reasons. Like plywood, large panels have the advantage in that they can be applied swiftly with consequent reduction in labor costs. Such panels would provide a uniform, smooth surface which will withstand permanent exterior exposure and on which a good quality paint will hold up for a long time.

Lapped siding is very popular and probably always will be in some form. It is possible to cut these panels into attractive widths for this type of application, and there is an added advantage here because wider boards may be obtained than are generally available in lumber siding. The lengths are such that there is a minimum of waste involved. One manufacturer is willing to rip panels into 8-, 16-, or 24-inch widths, and package and deliver them at a price that is competitive with other siding materials. That is the direction in which we are heading. If any kind of a market at all can be built up for siding, gable ends, and similar exterior uses, these outlets alone might well tax industry production.

Actually most of these products could be applied anywhere that plywood is employed because they have the inherent characteristics of plywood. They do have premium quality faces, however, so that uses are limited to location where this is of definite value. Plastic surfaced panels are not in competition with regular panels. They can be promoted for uses where their special properties are particularly valuable and thus contribute to expanding the markets of the plywood industry generally.

Plywood Association Program for Plastic Overlays

We are confident that there will be new special products in the future and that the volume of those now produced will increase. On this premise, the management committee of the Douglas Fir Plywood Association established the Allied Products Department. Perhaps a summary of the program set up for this division will serve to round out the discussion.

By way of preliminary explanation, the Douglas Fir Plywood Association is a trade promotion organization made up of 50 mills. These plants are located on the Pacific Coast between Calpella, California, which is almost down to the San Francisco area, and Bellingham, Washington near the Canadian border. It is a voluntary organization of these manufactures for promotion, research, and quality control of Douglas fir plywood. The Association is made up of a number of departments: Publicity, Field Service, Technical, Traffic, Statistical and Allied Products.

The relatively new Allied Products Department was set up for the purpose of working the plastic surfaced plywood and other special materials into the comprehensive industry program. Thus, Association experience and facilities are now being put to work for these new materials.

Considerable progress has been made to date. A lot of preliminary testing has been carried on in the Association Laboratory to build up information. We now have a standard set of uni-

form test methods for evaluating the properties of the overlays. These are tentative, but they are in workable form and are being employed. A quality control procedure including routine inspection and glue line testing has been established and is in force at the present time.

From the promotion standpoint, a uniform trade-mark for certification of quality will be branded on all products coming within the scope of the program and will be used in advertising and promotional literature. Industry wide advertising of overlays through the Association is in a formative stage, but the first material should be out before long. This will be educational in form and quite general.

Technical data pertaining to each product will be distributed by the manufacturer.

All manufacturers of plastic surfaced plywood indicate that their individual advertising campaigns will increase and we have devoted a considerable amount of time in the Allied Products Department to working with the manufacturers on the promotion of their own products.

The foregoing information is offered, not to publicize the Douglas Fir Plywood Association, but to show you that the plywood manufacturers have a real interest in plastic surfaced plywood and that they are willing to put time and money into its development. We are convinced, first—that overlays can perform a very significant function in better integrating production and in contributing to a well rounded marketing program; second—that with keen competition anticipated for the future, there will be a sharp up-swing in the development of new specialties and in the volume of production of such items now being made.

Discussion

Mr. G. Royer (Dant & Russell): Are any of the overlays produced as an interior type material?

Mr. Ritchie: Overlays are designed for both interior and exterior applications. However, the glue line in the base panel and the plastic surfaces are exterior quality without exception; suitable for permanent outdoor exposure.

Mr. Roy M. Carter (N. C. State College): The increased production of hardwood-faced Douglas fir plywood has developed new outlets for plywood. What effect do you expect the future production of such panels will have on the regular fir plywood production?

Mr. Ritchie: This question is a bit afield of our subject; however, I can offer this comment —Manufacture of hardwood faced plywood is bound to cut into the production of fir panels at the individual mill where it is produced. From an industry standpoint, however, I doubt that it will affect the total footage of fir plywood produced very much. I believe the hardwood will find new spots or retain old ones which might otherwise be lost by the fir panels. Hardwood will supplement fir production, not compete with it.

Mr. E. W. Wellwood (Canadian Forest Products, Ltd.): Will these plastic faced plywood panels supplement the present market of Douglas fir plywood or will they go into new markets?

Mr. Ritchie: Like hardwood faced fir plywood, the plastic overlays have a plus value which, I believe, means they can seek out new uses never before open to regular fir plywood and they may help retain present markets which might otherwise slip away.

Predicting Exterior Plywood Performances

N. S. Perkins

Technical Director, Douglas Fir Plywood Association

Data are presented to demonstrate the correlation between the durability of Exterior Type (commonly known as "waterproof") Douglas fir plywood and the percentage of wood-failure occurring in laboratory shear specimens subjected to the U. S. Commercial Standard boiling and drying test, followed by breaking in a tension-shear machine. A brief history is given of the development of industry standards and test procedures, including the introdu tion of blood as a phenolic resin extender. The industry's return to straight phenolic resins, their high performance records, and the subsequent fixing of 90 percent wood failure for glue approval are detailed. The adoption by the plywood industry of a more rigid quality control system including high wood-failure standards and improved sampling methods is related, with a description of test details. The conclusion is that insistence on high wood failure in laboratory tests of Exterior plywood is a practical means of assuring durable material.

Introduction

THE essence of this paper is the establishment of a definite relationship between laboratory tests and actual field performance of Douglas fir plywood made with a waterproof-type adhesive.

The Material

Exterior plywood is that manufactured to endure as long as the wood itself, in outside exposures. Durability will refer entirely to the capacity of plywood to withstand exposure without delamination. The discussions will be confined to Douglas fir plywood, which comprises more than 90 percent of all construction plywood, as well as a large percentage of that used industrially.

Douglas fir plywood, first produced in 1905 for drawer bottoms and backs of furniture, began to attain importance about 1930; by 1934 nearly 400 million square feet, based on the customary 3/8-inch rough thickness, were produced. That year marked the advent of hot-pressed phenolic resin as an adhesive in Douglas fir plywood. At first only one or two mills produced this more durable material so that in 1938 only twelve million feet, less than two percent of the total fir plywood volume, was made. Ten years later, however, in 1948, out of nearly two billion square feet total production, 625 million was of the exterior type.

Development of Performance Standards

In 1936 the Douglas Fir Plywood Association, or, for short, the DFPA, set up a small technical staff and began laboratory testing of plywood from the different mills. The industry had as its grading rules the U. S. Commercial Standard for Douglas fir plywood, which was revised every two or three years and which regulated the quality of the glue line with the innocuous phrase "shall be well manufactured".

In 1938, our industry for the first time included glue-line performance in revising the U. S. Commercial Standard. This covered both Exterior and Moisture-Resistant types.

In the tests for Exterior Type plywood, we had had little experience. Fortunately, the Forest Products Laboratory did have, from panels of various kinds of plywood which had been weathering for nearly five years. It was their conclusion that if standard plywood shear specimens revealed 50 percent wood failure after being subjected either to three and a half cycles of cold soaking and drying, or to two cycles of boiling and 145° F. drying, the panel could be expected to have a long service life. Just how long, no one was willing or able to predict. Since these recommendations represented the best knowledge available, however, they were accepted by our industry. When the new Standard for Douglas fir plywood became effective in November, 1938, all of our mills immediately began producing plywood to conform to one or both of the two standard types and the various grades established therein. The new type was designated "Exterior" to suggest its permanent outside use, whereas the more familiar type was named "Moisture-Resistant".

Beginning of Quality Control

During the spring of 1938, the DFPA acquired copyrighted grade-marks and trademarks and arranged for our mills to use these

grade-marks on their plywood, provided it would pass the new performance standards.

Inspection

Our inspection service was reorganized to give inspectors the responsibility of checking all phases of manufacture, especially the gluing schedules, and also of gathering samples from each mill for testing in the DFPA laboratory.

Details of 1938 Testing For Exterior Type Sampling

The Commercial Standard test for Exterior called for an average of 60 percent wood failure for the five test samples taken from each test panel, and a minimum of 30 percent for any one specimen. Those values were considered adequate and safe to insure the manufacture of durable plywood panels.

In our routine sampling and testing, we used these same limits. Because of the time consumed in making tests, we aimed at controlling quality trends. Another consideration was the destructive feature of the Commercial Standard sampling that called for pieces to be cut from the center and four corner areas of a panel.

Consequently, in cutting samples from panels selected for test, we took strips one or two feet long from the ends.

Test Procedure

In making the laboratory test for Exterior Type today, as in 1938, ten standard shear specimens, as illustrated in Fig. 1, are cut from the samples. Each specimen is 1 inch wide by 3⅛ inches long, with saw cuts one inch from either end and one inch apart. In a 3-ply specimen each saw cut extends almost through two plies nearly to the glue line, one from each side. Specimens are then boiled for four hours in vats as shown in Fig. 2, dried in an oven at approximately 145° F. for 20 hours, given another four hour boiling cycle, and broken, while still wet, in a tension-shear machine. Breaking or "shear" loads are recorded (Fig. 3). After the specimens have dried out, at least overnight, the percentage of wood failure over the one square inch of fractured area is estimated. Typical examples of wood failures are shown in Fig. 4. The two inner squares in each specimen are the fractured areas. Fig. 5 shows laboratory assistant "reading" a tray of shear specimens.

Boil Test Adopted as Routine

The boil test originally was merely an alternate for the regular three and a half cycle test of soaking and drying, followed by breaking in the tension-shear machine, and appraisal of the pieces for wood failure. Since the boiling test was quicker and more convenient, it was adopted as the routine test for our regular production, although both procedures are still used in making initial approvals of glues.

Exposure Fences

Shortly after Exterior plywood had been adopted as a type, a rather extensive exposure test fence was started near Tacoma in order to

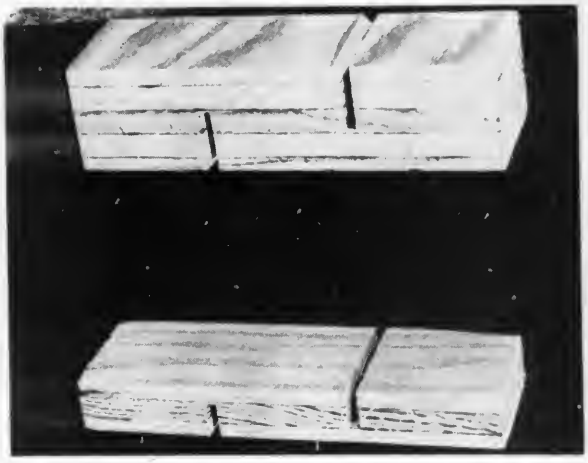


Fig. 1.—Standard shear specimen.

Fig. 2.—Boiling vats for Exterior specimens.

Fig. 3.—Breaking shear specimens.

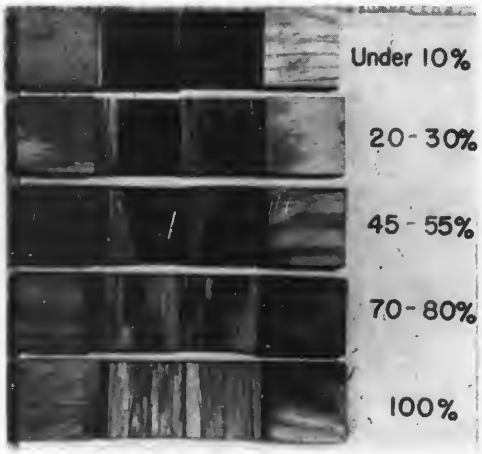


Fig. 4.—Typical shear specimens showing wood failure.

Fig. 5.—"Reading" wood failures.

ascertain just how Exterior plywood could be expected to withstand exposure to the weather, and to learn whether our criterion of durability was sound. Fig. 6 is a photo of a section of this fence in April 1949. A close-up is shown in Fig. 7.

Fig. 6.—Section of test fence, 1949.

Fig. 7.—Close-up of test fence, 1949.

It should be noted that the plywood samples on this fence undergo a considerably more severe test than do panels in normal service, which are nearly always painted, or covered by moldings or flashings, and if installed as we recommend, are always protected on the edges with a coating of thick paint.

In selecting a sample for the test fence, a fairly large piece was cut from a 4- by 8-foot panel. Then from this piece, ten 1- by 3⅛-inch laboratory shear specimens were prepared and tested to determine the average wood failure for that piece. Then a larger piece, about 10 by 12 inches but not standardized as to size, was removed from the original sample, assigned the same wood-failure reading and number as the laboratory test sample, and placed on the fence. It was not deemed necessary to select exposure specimens immediately adjacent to the laboratory specimens. Consequently, certain inaccuracies were bound to occur in comparing the wood failure of the laboratory sample with the performance of its companion sample on the exposure fence.

Introduction of Phenol-Blood Adhesives

Interest in Exterior plywood had stimulated research in resin adhesives, and before long, glues that were known as "phenol-blood" glues were being submitted to the industry as Exterior adhesives. They were phenolic resins with blood additives. Several of these glues passed the Commercial Standard test and, as they offered cost reductions, became quite popular as various mills installed hot plate presses. Accordingly, in 1940 about 48 million feet of Exterior Type plywood was produced, as compared to only 4.5 million in 1936.

First Warning of Phenol-Blood Failures

Late in 1941, several failures in phenol-blood glued samples had been noted on our fence, but because of the war, it was not until well along in 1942 that any further action was taken. A count was made then of the delaminations in the phenol-blood samples and those with the straight phenolic resins. An approximate picture of the relative performances as noted then is shown in Fig. 8. The increasing number of failures in the blood combinations is apparent, and was disturbing to us.

However, the exposure tests were recognized as accelerated and quite severe. Also, the field performance of the Exterior Type, as far as any complaints to the mills, appeared to be reasonably satisfactory. Most important was the matter of strategic materials. There had been an increasing demand for Exterior plywood by

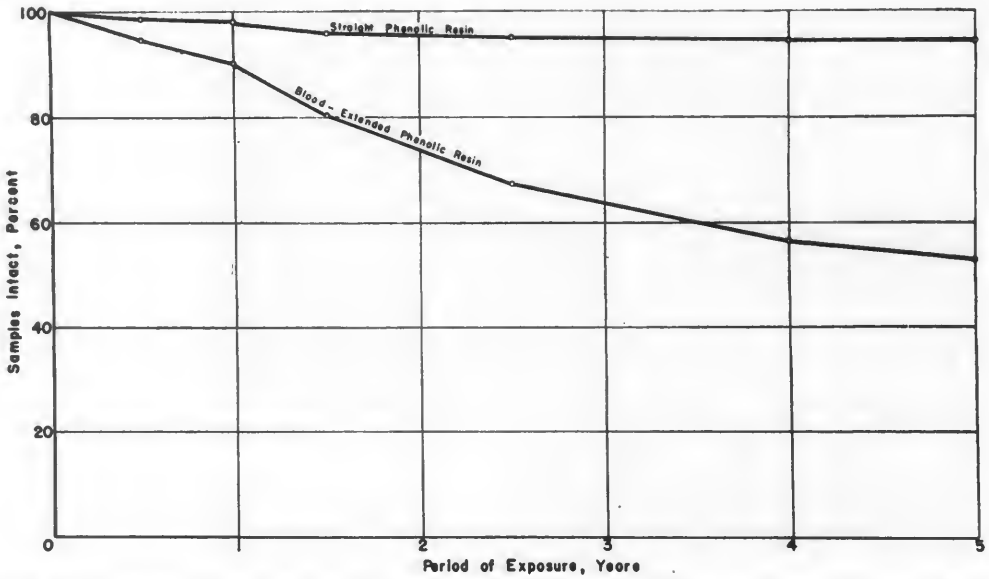


Fig. 8.—Comparison of the performance of the straight phenolic resins and the blood-extended phenolic glues.

the Armed Forces, and a serious shortage of phenol. Moreover, straight resin glues were not generally available to the mills, so no decisive action was taken.

Our tests were continued, however, and by the spring of 1943 enough evidence had been accumulated so that the industry felt justified in banning the use of the DFPA grade-marks on any plywood made with glue containing blood or other proteins. That prohibition was established as a policy by the DFPA and remains in effect today.

Period of Straight Resin Adhesives

Following the elimination of the phenol-blood glues for Exterior plywood, several glue manufacturers began furnishing straight phenolic resin adhesives. As a result, wood failure in laboratory tests became consistently higher. In fact, during a period of 2½ years, from about 1943 through 1945, the monthly average wood failure for our Exterior plywood ranged from 90 to 95 percent. This was during the war years when Exterior production had leaped to nearly 400 million square feet annually.

The Commercial Standard requirement for wood failure was still only 60 percent, as a minimum average, but after about a year of industry averages in the 90 percent bracket, we arbitrarily raised the DFPA standard to a 90 percent minimum for "approving" new glues. That was in 1945.

This, of course, raised the question of how high the wood failure should be in the U. S. Commercial Standard performance tests. We thought it should be higher than 60 percent but needed something definite on which to base our conclusion.

Possibility of Connection Between Wood Failure and Durability

There were several bits of evidence to make us suspect that there was a closer connection between wood failure and durability than we had been assuming. A report written in 1938 by Don Brouse of the U. S. Forest Products Laboratory, stated: "One of the first impressions gained in this study was the importance of the amount of wood failure developed when testing the joints."

Also, various other FPL reports describing results of exposure tests on different kinds of glues in plywood, all showed a correlation between wood failure and durability.

Furthermore, in our studies of blood-resin exposure-fence samples, we had found that the

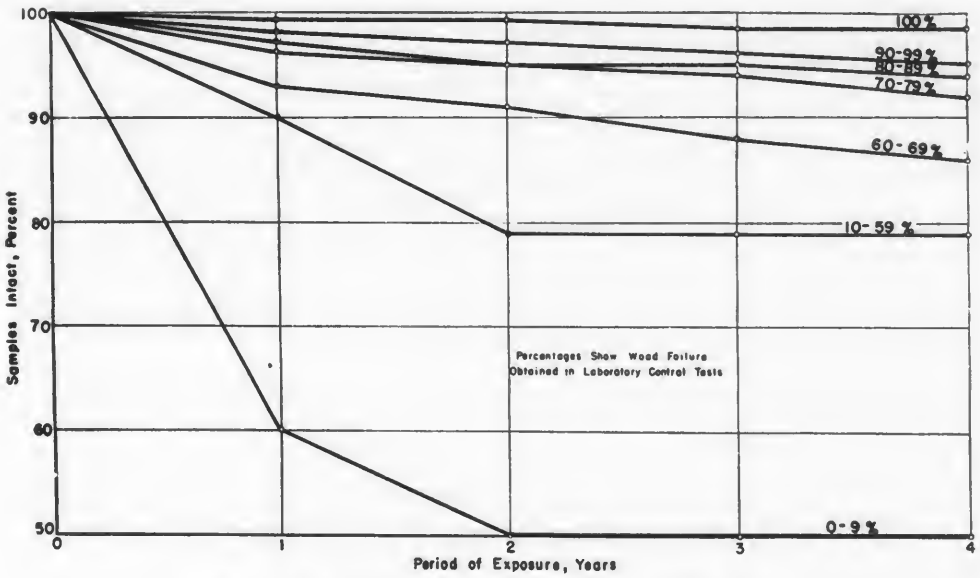


Fig. 9.—Initial analysis of performance—straight phenolic glues.

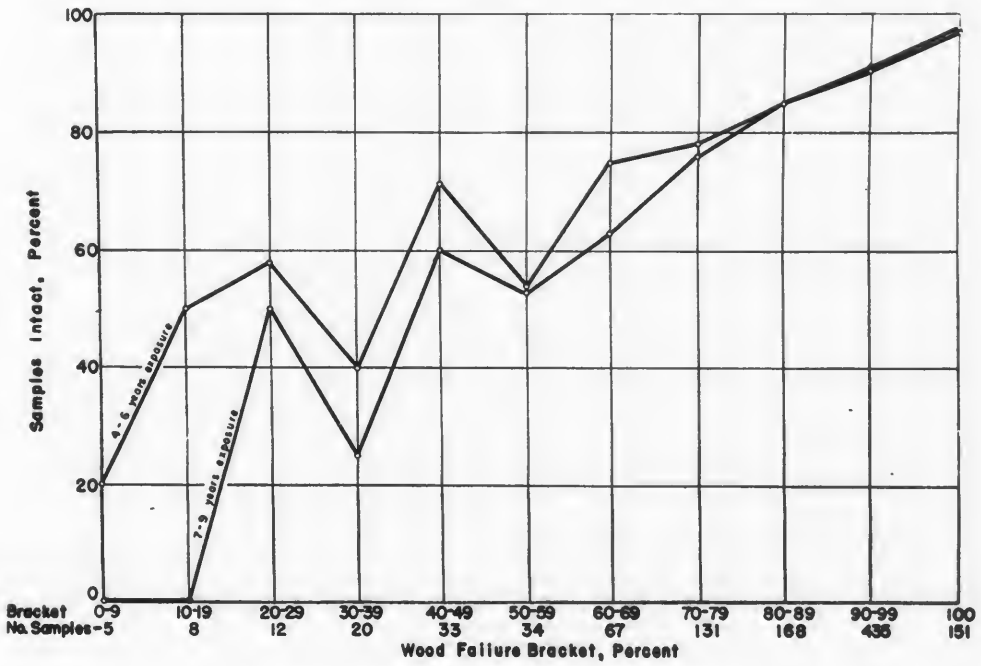


Fig. 10.—Group A, 1,064 samples of 3 phenolic resins.

percentage of failures, for samples labeled with wood failures under 60 percent, was much higher than for samples having wood failures over 60 percent. It seemed reasonable to us that for the straight resins, there might be a fairly high, critical wood failure percentage, below which plywood would begin to lose some of its durability, but above which, it would be a permanent material. To check this idea, samples on the exposure fence were classified into wood failure brackets of 90 to 100 percent, 80 to 89, 70 to 79, and so on; for each bracket we plotted the percentage of pieces still intact, that is without delamination, after various exposure periods. Delamination had to be positive, about 2 inches long, and $\frac{3}{16}$-inch deep.

From the fence data we obtained the curves shown in Fig. 9. The results were surprising and revealing. We had thought that the 90 percent bracket, and probably the 80 percent bracket would be essentially horizontal lines, that is, indicating little or no delamination. Instead, however, as the chart shows, we found a steady increase in the rate of failure as the wood failure decreased. The results from this study tended to confirm our belief in a close relationship between wood failure and durability of plywood. Instead of revealing a fixed wood failure percentage as a satisfactory production standard, however, the data indicated that the higher the wood failure, the greater the durability. Our goal in manufacture then had to be set as high as possible, without exceeding the limit of diminishing returns.

The data from these and other older samples were plotted as shown in Fig. 10, using the "percentage intact" as the ordinate and the "percentage of wood failure" as the abscissa. These curves were based on plywood made with three of the oldest straight phenolic resins. The upper one shows results of a four- to six-year exposure, as of 1946. The superiority of the high wood failure was apparent. The lower curve, seven to nine year exposure, shows results as of April, 1949. It is interesting to note the progressive failures in the lower wood failure brackets, whereas in the upper brackets, there is good evidence of stability.

In order to get a further check, we then analyzed the performance of approximately another thousand specimens which had been exposed from three to four years and which had been bonded with some twelve different adhesives in common use. The curve of those results is shown in Fig. 11. It should be noted especially that all of these samples had been placed on our exposure fence prior to 1945; that the matching of panels for the exposure fence with pieces tested in the laboratory for wood failure was not exact; and that in some cases, with 5-ply panels, failure had probably occurred in a different glue line from the one tested in the laboratory. Perhaps even more significant, nearly one half the failures occurred in samples made with one glue which was abandoned after being used only for a brief period. It is our belief, therefore, that the curves show a somewhat higher percentage of delamination than is to be expected for the corresponding wood failure, even with the severe exposure conditions at our fence. The trend of the curve, however, is similar to that for the older glues.

Finally, another series of 453 panels exposed only one year was examined, and these results plotted, as shown in Fig. 12, in the upper curve. In this case, however, we had improved our technique and were careful to select exposure samples from an area within at most one foot of those tested for wood failure in the laboratory. Furthermore, we had standardized on the use of 3-ply panels for the exposure fence. Out of 453 pieces, 41 with 100 percent wood failure rating showed no delamination; delamination on the test fence was less than one percent for panels rated in the 90- to 99-percent wood failure bracket. It will be noted that because of the smaller number of panels involved, larger wood failure brackets were used in order to smooth out the curve.

The lower curve in this figure (Fig. 12) shows the performance of these same 453 plywood samples two years later. Again, those with the high wood failure (85 percent and more) appear to be demonstrating their durability, whereas those in lower brackets are showing more delamination.

As a result of these studies, a new system of industry control for Exterior plywood was instituted. The 90 percent wood failure for approval of new glues was retained. In addition, each mill manufacturing Exterior Type plywood was required to attain each month at

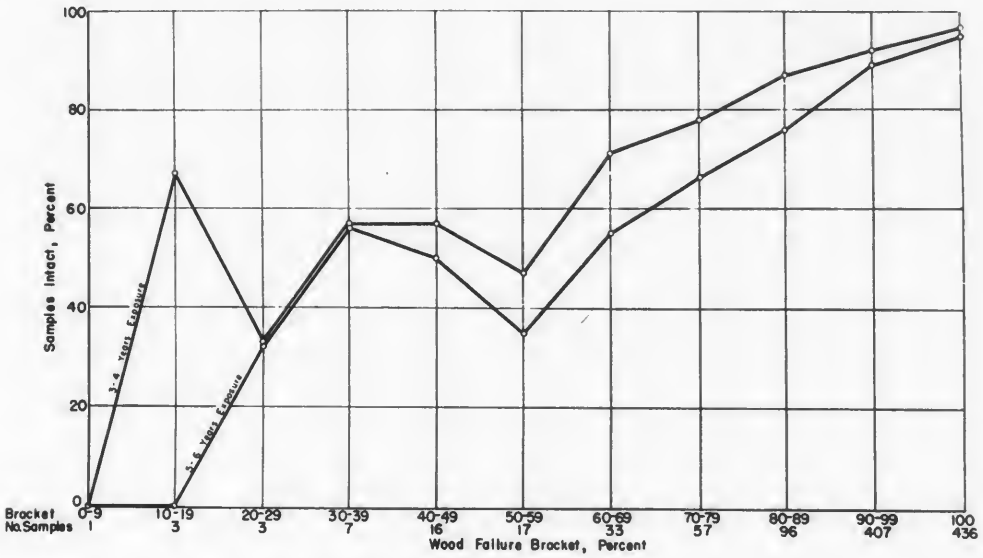


Fig. 11.—Group B, 1,076 samples of 12 phenolic resins.

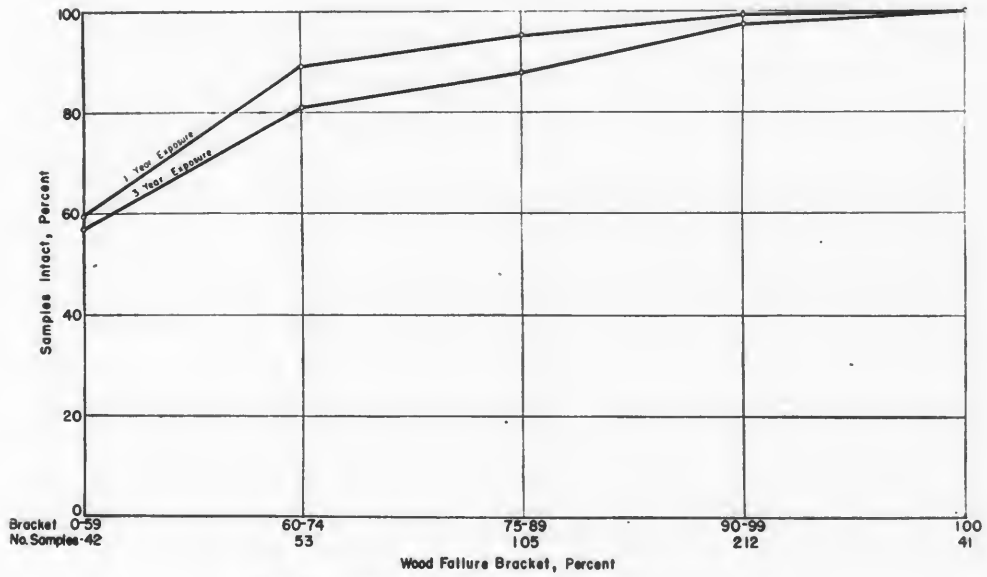


Fig. 12.—Group C, 453 samples of five phenolic resins.

least an 85 percent wood failure average in samples from not less than 25 panels made with any one adhesive.

The net result was a definite improvement in quality to a level that has never been exceeded over any long period. At the present time our entire industry has been averaging well above 90 percent wood failure, month after month, for more than two years.

Sampling

A new method of randomized sampling was also instituted along with the new quality controls.

Samples are now selected by chance in sets of four by means of small discs numbered from one to twenty to correspond with the maximum number of plate openings in any hot press. A sample, 1 by 4 feet is cut from the end of each test panel, and sent to the Association laboratory where specimens are cut and subjected to the standard laboratory test for Exterior Plywood. One variation from the standard test is that specimens are dried for only 16 hours rather than 20. We have not been able to detect any significant difference in either shear load or wood failure because of this, but we do find that the shorter period enables us to operate on a 24-hour cycle, without overlapping.

Estimating Wood Failure in Shear Specimens

One important point in the technique of reading wood failure is not mentioned in the Commercial Standard. It is permitting the specimens to dry out overnight after they have been broken in the shear machine, before the wood failure is read. If specimens are estimated when wet, some of the more transparent wood fibers may be overlooked and values will be too low.

In order to maintain as much uniformity as possible in the technique of reading wood failure, several steps have been taken. One of the most important is the training of our laboratory personnel. A considerable help in this connection is our "library" of 300 wood failure specimens ranging from 0 to 100 per cent. These have been checked several times by different technicians at the U. S. Forest Products Laboratory, and have been read repeatedly at intervals by all of our laboratory staff who estimate wood failure. A careful correlation has been established so that, as far as possible, all of our technicians read wood failure alike.

Attempts have been made to set up mechanical devices for reading wood failure. Colored dyes and fluorescent dyes have been tried out, but so far nothing has proved as efficient as ordinary visual examination.

Exposure Tests

As noted previously, all of our fence samples are now taken adjacent to those broken in the laboratory, making sure that the same piece of crossband extends through both types of sample.

Today, every new approved glue, when used in plywood production, is represented on our test fence by 150 permanent exposure samples, as well as 8 sets of 24 samples for periodic testing. The former are examined at regular intervals for any sign of delamination. One set of the 24 test samples is also brought in at inspection time, subjected to the boil test, and then read for wood failure, to ascertain whether there is any progressive decrease that might indicate a weakening of the glue bond, from year to year.

Fig. 13 shows the wood failure-durability relationship for plywood made with eight currently used straight phenolic resin adhesives. Although exposed only one year, the results appear to confirm the advantages of well-matched samples. The higher wood failure pieces, it will be noted, have shown no signs of distress to date.

A rather complete summary of virtually all our test records will be seen in Fig. 14. Here we see the record of nearly 7500 samples, exposed from 1 to 8 years. This is most important chart of all.

The curves for the various wood failure brackets, 100 percent, 90 to 99, and so on, show the percentage of test samples still intact after the different years of exposure.

As already pointed out, our present sampling methods and laboratory procedures are considerably better than when we started our test fence some ten years ago.

The overall performance trend, however, appears clear. High wood failure is a necessary attribute for plywood durability.

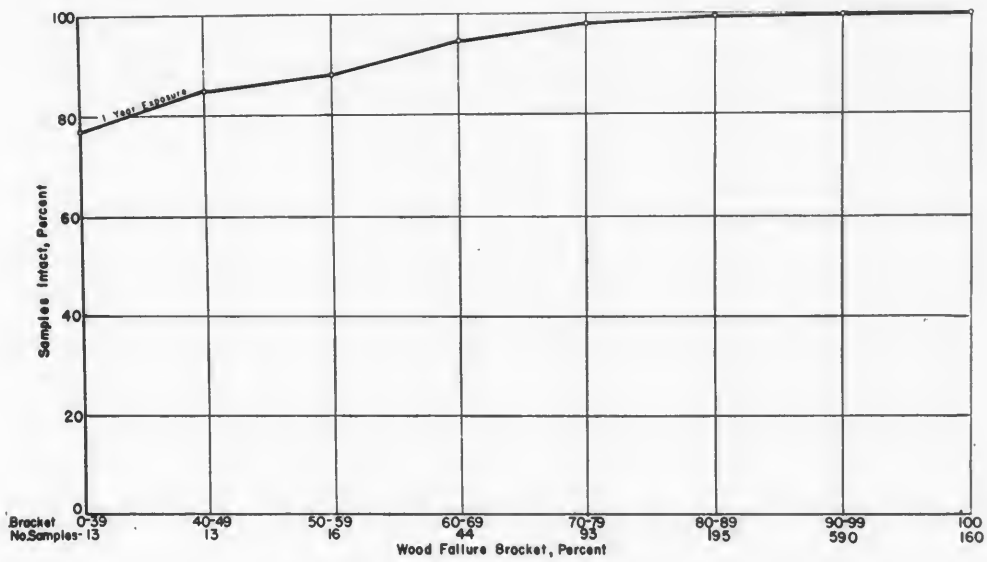


Fig. 13.—Group D, 1,124 samples of eight phenolic resins.

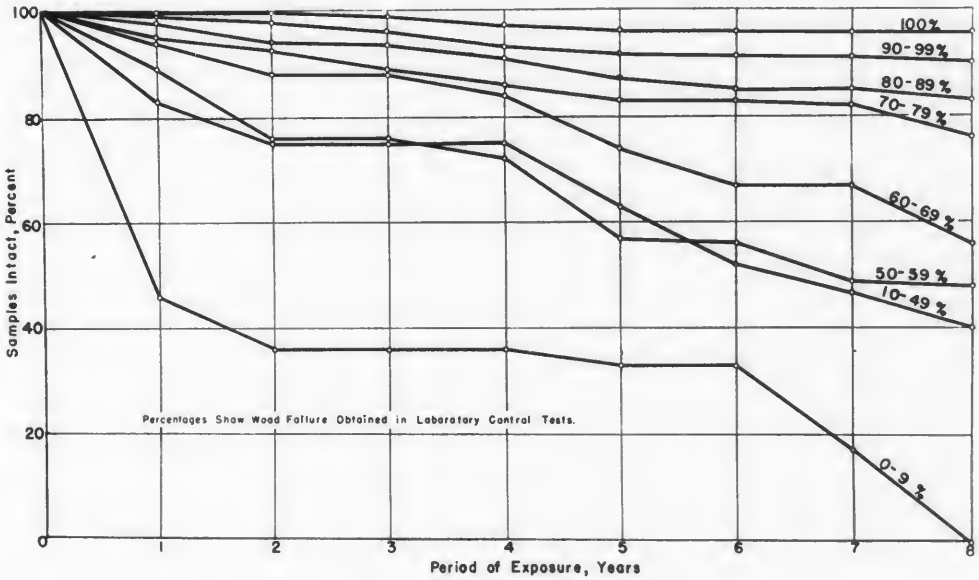


Fig. 14.—Performance of plywood on exposure fence, all approved glues.

Controversial Items

Although wood failure is now commonly accepted as the criterion of Exterior plywood quality in our industry, there are some controversial points.

One that crops up periodically is that high load or shear strength should be acceptable, per se, or be at least an important factor.

We can find nothing in our experience to justify that belief. The dot chart, Fig. 15, shows a typical set of tests with shear load as abscissa and wood failure as ordinate. Each dot is the average of ten shear specimens from one sample of Exterior Type.

In general, high loads are accompanied by high wood failures. Only in rare cases do we get wood failures under 60 percent with shear loads over 250 psi.

High wood failure often is recorded, however, with low loads, but when this occurs throughout a test run for approval of a new glue, another test is requested. With such low loads the glue has merely demonstrated it is strong enough to break weak wood. Since some of our specimens run over 300 psi. and even, though rarely, above 400 psi., after the boiling cycles, we think the glue joints should show at least 90 percent wood failure.

It seems logical that dense, strong veneers of Douglas fir, or of any species for that matter, as they expand and contract under changing exposures, will exert greater internal stresses on a glue line than will softer and weaker woods. If that is true, then I believe it is consistent to expect the glue bond between high strength veneers to resist the ultimate shear stress that may be imposed through the wood, and to require always a high percentage of wood failure in the standard performance test.

Another hypothesis on this matter of wood failure is that delamination, if it occurs in an Exterior Type panel, will always be in an area of low wood failure, and that the reason less delamination occurs in panels showing high wood failure is simply a matter of probability. In other words, a panel with 90 percent wood failure average has less chance of having an area testing only 10 percent, than does a panel with a 50 percent average, for example.

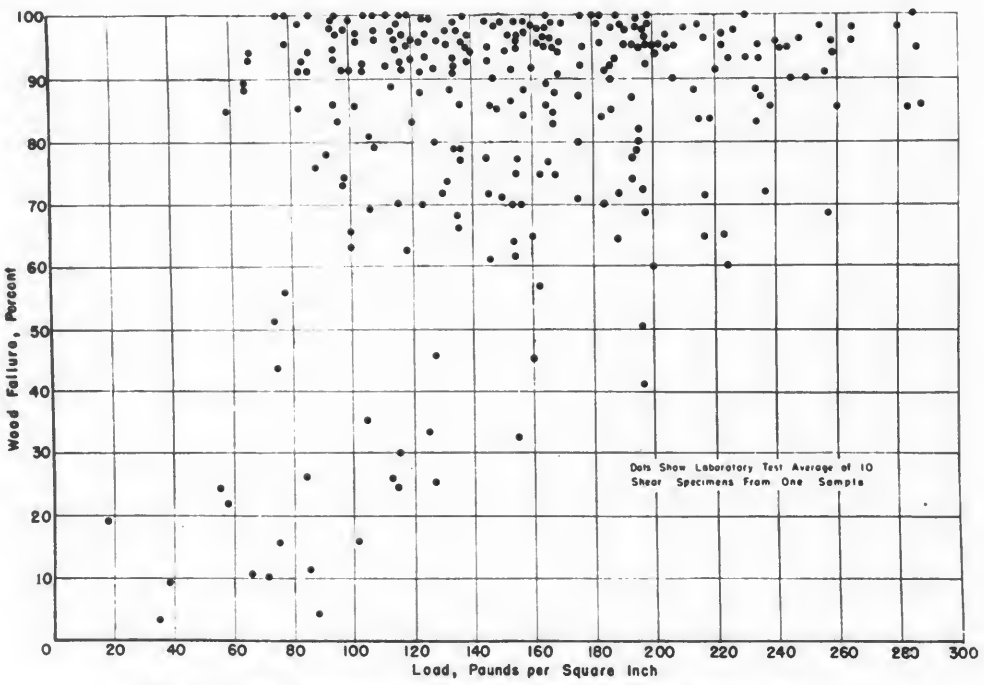


Fig. 15.—Load and wood-failure relationship for three typical phenolic resins.

This is difficult to determine when we are limited to destructive testing, but it does offer a possible explanation of why plywood with high wood failure tests stands up under exposure better than that with low tests.

Unexplained

One apparent discrepancy in our wood-failure-durability relationship has not been explained. Some of the early blood-extended phenolic resins showed high wood failure—90 to even 100 percent—and yet quite a high percentage of failures developed in companion pieces on our exposure fence. These results may have been due to inadequate matching of samples (as already discussed) and to non-uniformity of glue bond in the samples.

Finally, it is possible that bacteriological action on blood or other proteins constitutes a potential glue-line weakness that our present tests fail to reveal. That is one reason we continue to prohibit any protein in our Exterior glue lines.

Conclusion

We have tried to show how our performance standards were established, were used for several years, and then found inadequate; why they were increased in severity and why we arbitrarily ruled out proteins or amylaceous material from any Exterior adhesive. Then we traced the improvement in quality and our efforts to ascertain from the exposure fences a safe minimum percentage value for wood failure and how we discovered what appeared to be a correlation between field performance and laboratory tests.

Then came the more complete study of our test results, and final acceptance by our industry of wood failure as a criterion of plywood durability.

Certainly the last word on this subject is far from being expressed.

Our technique can be improved; our tests probably can be simplified. Certain questions still remain which require continuing studies.

One simple fact emerges. The field performance of Exterior Type Douglas fir plywood has been virtually free from glue line complaint for several years. In other words, the standard of wood failure now in use in our industry has proved effective in raising and maintaining quality.

Acknowledgments

Finally, this paper would be incomplete without grateful acknowledgment to Gus N. Arneson, formerly in charge of our laboratory, who set up the original test procedures and exposure fence; also to John Ritchie, laboratory chief from 1945 to 1948, and to Robert Ripley, now in charge of our quality control work, without whose joint assistance and full cooperation, our wood failure-durability correlation and present testing controls could not have been developed. Appreciation is also due W. D. Page for his assistance in preparing data, charts and slides for this paper.

Discussion

Mr. C. Latimer (Nickey Brothers, Inc.): I notice that your investigation was concerned with wood failure rather than a combination of wood failure and shear strength. What are your comments on the idea that a panel with relatively low wood failure is equivalent to one of high wood failure provided that the shear strength is sufficiently high? Could low wood failure on a strong wood still yield good exterior panels?

Mr. Perkins: Our results indicate that for durability you need high wood-failure regardless of load. A low percentage wood-failure really means a high percentage of glue failure. However, as brought out in the paper, a glue that develops high wood-failure with low *loads* hasn't necessarily demonstrated durability. The glue has merely shown it can break weak wood and might conceivably fail with dense strong woods that presumably develop higher internal stresses as they expand, and contract than do weak non-dense woods.

Mr. E. G. Stern (Virginia Polytechnic Institute): Are the observations made on delamination of fence specimens representative for the service behavior of the larger-size panels in consideration of possible occurrence of greater internal stresses in larger-size standard panels than in small-size fence specimens?

Mr. Perkins: We have no data on full size panels.

Mr. A. H. Rauch (Plywood Research Foundation): Size of panel should have little if any effect due to the fact that veneers are at right angles and stresses should be of the same intensity per unit area of glue line regardless of the size of the exposure test specimen.

Mr. Perkins: I believe that is true.

Mr. E. Ellis (University of Idaho): What comparison can be made with current commercial standard exterior tests for Douglas fir and similar requirements for hardwood plywood of various "waterproof" grades and composites of Douglas fir cores and hardwood faces? That is, does high wood failure indicate superior qualities in these products as well as in Douglas fir?

Mr. Perkins: We are seeking data on other species but in general I believe the theory of high wood failure holds in any combination of woods.

Mr. A. Elmendorf (Elmendorf Research, Inc.): When exterior plywood was first brought out, some said that the wood fails even when the glue holds. What does the Douglas Fir Plywood Association test fence show on this?

Mr. Perkins: We find some splitting of wood but do not have any statistics as to extent. It is quite rare, apparently more of a shake or separation of annular rings.

The Softwood Plywood Market—Present and Future

C. E. Devlin

General Sales Manager, Simpson Logging Company, Seattle, Wash.

An attempt to analyze the principal markets for softwood plywood, those which may be expected to increase in the near-term future, those which may be expected to decline, and those which may be expected to maintain the status quo. Also some discussion of the markets which may be expected to increase substantially over the long term. A statement as to present production and projected increases for 1950. An analysis of the overall demand potential for softwood plywood based on market considerations, and certain business indices.

PINNING down the markets for softwood plywood precisely continues to be an elusive exercise. This is so because the product has such a multiplicity of uses in so many markets. It is truly the wood of a thousand uses, and as the Douglas Fir Plywood Association has demonstrated on numerous occasions, these 1,000 uses can be cited in detail.

Fortunes of the softwood plywood industry are, obviously, tied closely to the fortunes of the building industry. But the building industry itself has many facets, and many forces working within it which are not always working in the same direction.

For instance, new house construction may (very often does) trend downward at a time when commercial and industrial building is rising. Thus, even within the category of building itself, it is hard to gauge demand as it may affect a particular industry, such as the softwood plywood industry. And building is only one component in the makeup of plywood demand, as will be demonstrated.

As a contrast, the market for stock doors *can* be accurately measured and even forecast. The number of doors per house, for instance, can be predicted; the size of the replacement demand is fairly well known; the demand for doors in the farm market can be estimated; the demand in industrial and commercial building is also rather easily pinned down; and, inventory demand can be determined by periodic sampling. Therefore, it is possible to know within narrow limits how many doors are being consumed at any time, and what the prospects are for the immediate future. There are simply no other markets for stock doors, and fluctuating prices will have little affect on basic demand.

But, in the case of softwood plywood, delineating markets and measuring demand is no such easy matter. One of the large markets for the product falls outside the building industry, and is that segment known broadly and loosely as the "industrial" market. Industrial uses are typically "cut-up" uses where the plywood becomes a part of another item of merchandise. Furniture is a typical example of an industrial use of softwood plywood, and millions of feet have gone into such items as radio cabinets and now television cabinets.

As a matter of fact, the industrial market at one time undoubtedly was the largest market for softwood plywood. In the 20's panels were used widely in the automotive industry for floor boards, door panels, instrument panels, trunk bottoms, running boards, and similar uses. Today for many reasons the automotive demand is a relatively small part of the overall industrial demand for softwood plywood.

A Breakdown of the Markets

A study of softwood plywood markets made by the staff of the Association and following accepted statistical methods indicated that roughly 45 percent of the production of softwood plywood went into industrial uses, and 55 percent into construction uses, of which 40 percent was housing, and 15 percent heavy construction. These studies were made at the time plywood was being produced at a rate slightly less than 2 billion sq. ft. per annum. That this percentage still holds now that the industry is running at an annual rate of about 2½ billion sq. ft. is extremely doubtful. There is evidence that the balance has swung more heavily toward construction uses because of the continuing high level of building.

This may be the place to insert a list of the major markets for softwood plywood.

I. *Industrial markets*
- Railroad
- Automotive and other transportation
- Furniture and luggage
- Displays and signs
- Store fixtures
- Packaging and crating
- Millwork and doors
- Templates
- Toys and games
- Pallets

II. *Construction markets*

A. Housing
- Subflooring
- Wall sheathing
- Roof decking
- Exterior siding
- Soffits
- Gable ends
- Interior walls and ceilings
- Built-in cabinets and millwork
- Base for resilient floor coverings

B. Heavy construction
- Concrete forms
- Protective fencing
- Gussets
- Trench sheeting
- Beams

C. Farm construction
- Grain bins
- Silos
- Hog houses and feeders
- Chicken houses
- Barns
- Dehydrators

D. Marine construction
- Planking
- Decking
- Bulkheads
- Cabins
- Thwarts
- Knees
- Tanks, bait and fish
- Hatch covers

No brief is held for the completeness of this list. However, these are the major markets, if awkwardly classified. In general, it is impossible to state the exact footage that is going into any of these markets and in many cases even the trend is difficult to perceive because of the lack of accurate data.

Where the Trend is Upward

For the near-term future, however, it can be predicted safely that the following markets will be growing in importance for plywood, both in footage required, and as a percentage of total plywood produced:
- Furniture
- Displays and signs
- Store fixtures
- Pallets
- Concrete forms
- Protective fencing
- Exterior siding
- Subflooring
- Railroad car construction

Reasons for the above predictions are not academic, but are based largely on present and predicted activity in the above markets and the state of competition within those markets. For instance, a continued high level of heavy construction, particularly public construction, and the amount of concrete work that will be needed, is the basis for the prediction that the demand for plywood for concrete forms will increase. In this field softwood plywood has virtually no competition.

Demand for plywood as exterior siding, as another example, is sure to increase because of the continued decline in availability of wide boards. Plywood will serve as a substitute for wide boards in both residential and commercial construction.

Where Declines May Come

Near-term declines in demand for softwood plywood can be expected in the following markets:
- Farm construction
- Interior walls and ceilings
- Marine construction
- Packaging and crating

A decline in use of softwood plywood in farm construction is predicted largely because farm income is sure to decline and competition will be keen, with plywood at some price disadvantage.

Price levels also are basic to the prediction that interior walls and ceilings will be of relatively less importance to plywood in the months immediately ahead. The same applies to packaging and crating.

Other markets can be expected to maintain present importance for the near-term future.

In looking ahead to the long-term future the only safe prediction is that some markets will become tremendously more important than they are now. These are the markets in which plywood's peculiarly advantageous physical properties (i.e. strength with light weight, large sizes, durability and workability) combine to produce attractive cost savings, particularly labor savings, or important design and aesthetic results. Use of plywood for subflooring is an illustration of a use important because of inherent labor savings. Use of plywood for exterior siding is an illustration of a use which will become more important largely because of design considerations.

Some Markets Easily Forecast

The size of certain markets for softwood plywood can be measured rather precisely and forecasts for the future made. One of these is the tobacco hogshead market, which, because of the limited number of users and the precise planning that goes into this use, can be figured accurately. It will account for about 30 million sq. ft. annually for the next few years.

Another market that lends itself to an accurate analysis is the use of softwood plywood for railroad car construction, particularly freight cars and refrigerator cars. The total demand for plywood in the railroad market is, however, pretty much of a conundrum since there are dozens of items such as track shims, journal dust guards, portable buildings, and many other miscellaneous uses that add up to considerable footage, but are hard to pin down.

Still a third market that can be estimated accurately is the use of softwood plywood in stock door manufacture. It is known that the average panel door requires about ten sq. ft. of ¼-inch plywood, and the average flush door requires 30 to 35 sq. ft. Since the production of panel doors and flush doors is easy to obtain, this market can be gauged accurately. In 1949 the demand for door panels represented a market for about 125 million sq. ft. of softwood plywood, on a ⅜-inch three-ply basis.

More Variable and Unpredictable Markets

At the other extreme, i.e., markets for softwood plywood that are almost impossible to measure, are most of the uses for plywood in house construction. As yet no particular pattern has formed, and an average figure representing the plywood consumed per sq. ft. of floor area would be meaningless. Consumption of plywood would vary with the design of the house, the type of construction, the climatic conditions, and so many other variables that averages except over long periods of time would be of little value to the market statistician.

For instance, a builder in one area might use softwood plywood for subfloors and nothing else. Another builder producing almost the identical house might use panels for outside siding, for soffits, and for gable ends, but *not* for the subflooring.

Still other builders will use plywood only for the millwork in a house, and not for any of the structural elements.

It is likely that over a period of years these housing uses will settle into a pattern, particularly when price levels become more stabilized and design trends are more evident. When this occurs, building products will seek their normal and natural markets, and the distortions that have been inherent in the years of shortages will disappear.

For instance, it is now becoming clear that in many areas of the United States ⅝-inch or ¾-inch plywood is becoming the standard subflooring material. The labor savings inherent in the use of large sheets of plywood, as compared with competitive items, are so great that relatively wide fluctuations in the price of plywood, or the price of the competitive materials, seems to have little effect on the demand for plywood in this market.

Another demand that seems to be conforming to a pattern has been influenced by design. Use of a wide overhang in house construction in many areas has led to an increased use of plywood for the soffits, and this is apparently a market also that plywood can serve because it has almost no competition.

Demand factors have not crystallized, however, in the use of plywood for wall and roof

sheathing, outside paneling, or inside walls and ceilings. In these markets competitive factors are still very active, and softwood plywood demand is sensitive to price changes, to changes in design preferences, and to such artificial blocks as building codes, local labor requirements, and other sectional prejudices.

As an illustration of this, $\frac{5}{16}$-inch plywood can serve adequately as wall sheathing, but the price factors are normally in delicate balance. If the plywood price goes up rather substantially, and the competition, which is usually boards, remains stationary, the cost-conscious builders will switch from plywood to boards. In some areas also building codes have ruled out the use of $\frac{5}{16}$-inch plywood, although protests have been registered and it is likely that this situation will be changed.

Another illustration is the matter of design preference. In the so-called modern or contemporary design, there is little prejudice against large panels for exterior siding; and, in fact, for many architectural effects, wide panels have an aesthetic advantage. Furthermore, there is a long-range trend in favor of plywood for siding material because of the growing scarcity of wide boards. Ultimately, it may be that plywood will have to fill this demand, and if the design preference is for 16-, 18-, or 24-inch boards, the standard 4 by 8 panels will be cut to those dimensions. Even now this is being done regularly.

The Need for Reliable Market Figures

Summing up, it can be said that the market statistician finds it very difficult at this stage to reduce plywood demand and plywood markets to reliable square footage figures. For almost 12 years, from 1938 to 1950, the need of such figures was largely academic. For a period from January to August, 1949, when effective demand appeared to be lower than available supply, the desirability of such market information was spotlighted.

Parenthetically, even during that period in 1949 end-use consumption of plywood was proceeding with only a slight drop off in intensity. Certainly the decline in demand at the consumer level was nowhere near the decline registered at the wholesale or manufacturing level. This was evidenced by the fact that during those months stocks in the hands of distributors and dealers were reduced virtually to zero. Furthermore, when the turn-around came in August and confidence had returned in distribution channels orders flooded back to the mills in a volume that sent order files to all-time peaks. This condition still applied throughout the first quarter of 1950, despite the fact that production had increased substantially and is currently running at a level higher than 50 million sq. ft. per week. This is by all odds the all-time peak of production. If maintained for the balance of the year, 1950 production will show a 25 percent increase over 1948 and 1949, which in themselves were boom production years.

Current Production

This may be the point at which production figures should be introduced, since it is the contention that the demand for Douglas fir plywood, at existing price levels, is sufficient to take care of the entire present and projected capacity of the industry.

Following is the production of Douglas fir plywood for the weeks of 1950 reported by the Douglas Fir Plywood Association:

Week of	Square Feet ⅜-Inch 3-Ply Rough Basis M Sq. Ft.
January 7	34,237
January 14	42,108
January 21	35,958
January 28	42,894
February 4	34,317
February 11	39,538
February 18	44,755
February 25	47,887
March 4	46,770
March 11	47,837
March 18	48,464
March 25	50,155
April 2	50,400
April 8	48,647

Four additional Douglas fir plywood plants will soon be adding to the figures above; and, when they are rolling smoothly, new plants should add another 2,500,000 sq. ft. to the weekly totals. Thus, by July 1, Douglas fir plywood production may be running at the rate of at least 53,000,000 sq. ft. a week.

In addition to Douglas fir plywood, softwood plywood volume is increased by a considerable production of pine plywood, and by some production of minor species. Pine ply-

wood is, of course, the predominant other softwood plywood produced. Although figures by weeks are not readily available, it is estimated that production is about 2¼ million sq. ft. per week based on an estimated annual production of 115 million sq. ft. on a ⅜-inch basis.

These figures added to the Douglas fir plywood figures would give a total softwood plywood weekly production by July 1 (assuming a continuing demand of 55 to 56 million sq. ft. per week), of 230 million sq. ft. per month, or a early rate of 2,700,000,000 sq. ft.

Market vs. Production

The question now is, "Are there markets sufficient to absorb this volume of production in normal times?"

It is obvious that no one knows the answer to this, for no one yet knows the answer to the question: "What is normal post-World-War-II business?"

But there are means of calculating whether or not there is sufficient demand from the plywood markets to absorb increased production.

Studies relating plywood demand in a normal pre-war year, 1940, to certain indices such as Sales Management's measure of general business activity, new house construction, and total construction have been carried on for a number of years.

If the demand for plywood in 1940 resulted from a combination of certain factors in consumer buying income, general business activity, new house construction, and total construction, those same relationships should exist today, assuming that competitive conditions remain the same, that price levels are consistent (that is, they would be higher, but in the same general relationship) and assuming that there have been no great basic technological changes in construction, in labor usage, and in the quality of the product itself.

That assumption, of course, is a very wide one, and probably could not be defended successfully for lack of factual evidence.

However, these studies, though crude, do give every indication that a relationship exists between plywood demand, and the level of general business activity and construction.

Furthermore, there are ways of correcting the relationships to eliminate the errors in the basic assumptions, particularly in the matter of changing price levels. It is possible to determine accurately the changes that have taken place in the price level for plywood, as compared with competing materials and as compared with the general wholesale price levels.

Annual plywood demand as derived from these calculations exceeds 2 billion 800 million sq. ft., based on the maximum adverse effect of price increases, and minimizing the expansion of plywood markets that has taken place during the war and postwar periods.

Recognizing that these are rather crude studies, the industry in the fall of 1949 retained Dr. Charles F. Roos of the Econometric Institute of New York City to refine and revalue the demand factors.

It was interesting to note that Dr. Roos's preliminary figures, as released in November 1949, showed a conservative demand figure for 1950 of 1 billion 800 million sq. ft. In his analysis in February, 1950, Dr. Roos warned that the studies were still preliminary, but that it was becoming increasingly evident that plywood was indeed a growing industry and that the rate of growth was again accelerating following the lull during the war and postwar.

It is believed, therefore, that the use of refined statistical methods by Dr. Roos ultimately will provide the industry with a dependable series of demand statistics, based on the expanded postwar markets for softwood plywood.

Some Predictions

It is safe to predict now, that barring a major depression, which would affect plywood and virtually every other industry, the plywood industry can look forward safely to selling its production, based on the optimum capacity figures mentioned above. The only other qualification is one of price levels.

Softwood plywood cannot expect demand to continue without regard to price levels. The industry discovered that very dramatically in late 1948 and 1949, when demand pushed prices far out of line with the general level of prices for building commodities, and particularly far out of line in relation to the competitors of softwood plywood, excepting lumber.

Lumber is, of course, the major competitor of softwood plywood in most markets, and the price levels in lumber went as high proportionately as did price levels of softwood plywood.

Softwood plywood prices had increased almost 200 percent by 1948, as compared with 1939. In 1949 the prices declined abruptly about 35 percent from the high to a point not much more than 100 percent over the 1939 figures.

Parenthetically, it must be pointed out that in most of this discussion the figures are those of Douglas fir plywood because it is the volume item, and also because statistics are more readily available for this species. It should be pointed out that this discussion of prices is not necessarily typical of ponderosa pine plywood, since the price levels of the latter did not decline as drastically as did those for fir plywood in early 1949.

From the low point in price levels reached during August of 1949 prices of fir plywood have increased about 25 percent, or to a point about 140 percent above the 1939 price levels.

At present price levels it is obvious that plywood is not out of line with its principal competitor, lumber, nor with the general price level. If the prices remain at this level, the demand figures should be accurate.

Price and Competition

Plywood prices, compared with certain important competitors such as hardboard, gypsum wallboard, or even insulating board, are not favorable. Only the overwhelming advantages of the material in its adaptability to so many different uses makes it a preferred item for the building material dealer. The versatility of plywood panels is, in fact, the key to the problem of demand.

Plywood competes with lumber in the subfloor of a house; it competes with hardboard in furniture and many other industrial uses; it competes with plaster, with gypsum wallboard, with insulating board, and with hardwood plywood for interior walls and ceilings; it competes with the highest grades of lumber in marine construction; it competes with steel and aluminum in many farm uses, particularly grain bins; it competes with metal in railroad car construction; it competes with oak staves in tobacco hogsheads; it competes with metal and with lumber in cabinets and mill work. This list could go on and on.

But, the product has no single competitor for all its uses and no one product on the horizon can challenge its versatility as yet. As Fortune magazine has said, plywood is the nation's most versatile building material; the one that can do more building jobs than any other.

It is the sincere belief of many men in the industry that the markets for softwood plywood will be limited largely by available raw materials.

Service That Sustain Markets

Finally, in any discussion of markets it is important to point out that the softwood plywood industry has been fortunate in having invested substantial sums of money in quality control, advertising, promotion, field service, and research. Without this intelligent, sustained effort devoted to the cultivation of existing markets and the development of new markets, the growth of the markets for softwood plywood would not have been as rapid, nor as solid. The Douglas fir plywood industry, through its association is now spending upwards of $1,000,000 a year on these various activities.

In addition, individual companies within the industry are spending additional sums on advertising, promotion, research, and general sales effort, with the result that the industry overall is doing a fine job in the development of its markets.

Summary

1. The analysis of the plywood markets in 1948 indicated that the markets were 40 percent house construction, 15 percent heavy construction, and 45 percent industrial uses. These percentages are changing materially as production increases. More plywood percentagewise undoubtedly will go into housing. A survey of 1,000 builders showed that during 1948 the average builder used less than 400 sq. ft. of softwood plywood per house. Undoubtedly this low footage was due to unavailability of the material. As the material became more readily available in 1949 and early 1950, through increased production, a great expansion in the consumption of plywood in housing occurred, for a large latent demand existed. Last year probably 100 million sq. ft. went into prefabricated housing, and this percentage, too, will increase as the material becomes more available. The volume going into prefabricated

housing in 1950 could well approach 200 million sq. ft.

2. There are certain markets that can be accurately measured, and others that can not. For example, in prewar years the volume of plywood used for concrete forms could be rather accurately determined because the industry produced a specific grade for that use. Today, while there is still a concrete form grade of plywood produced, it cannot be taken as an accurate gauge of the amount of plywood used in concrete form construction because many other grades, particularly exterior types of plywood, are also used in form construction.

3. There are methods of measuring the size of markets and overall demand for softwood plywood, by relating them to certain indices, particularly new housing starts, total construction, and general business activity. These statistics are particularly important in determining market potentials in any particular state, or in the 63 major trading areas in the United States.

4. As a means of refining these measures of demand, Dr. Charles F. Roos of the Econometric Institute is making additional statistical studies for the industry, but the results so far are preliminary.

5. Production of all softwood plywood is currently running in excess of 52¼ million feet per week, and by summer will be at least at the 55¼ million foot per week level.

6. It can be predicted that the markets for plywood will absorb this production if (a) general business conditions remain on a fairly even plateau, and (b) there are no substantial plywood price increases in the near future.

Discussion

Mr. R. C. Fraunberger (Philco Corporation): You stated that the Douglas fir plywood industry spends one million dollars per year in promotion. The wood industries are rather backward in this matter—when compared with other industries that glamorize their production. Shouldn't more time, effort, and money be spent in merchandising wood-plywood and lumber. We have lost many markets. Let's try to recapture some of them.

Mr. E. W. Wellwood (Canadian Forest Products, Ltd.): What is your opinion of the future market of decorative softwood plywood panels as compared to hardwood-faced plywood panels. Do you consider the present demand for decorative softwood plywood panels to be a "fad" that will in time taper off, and if so, how long do you think this fad will last?

Mr. Devlin: The future of rotary-cut Douglas fir plywood is not in the decorative field except for novelty items like Weldtex. Volume use of Douglas fir will be for structural uses. These will be overlaid items that will have decorative value, of course. This is general and there will be exceptions for some people do like grain of Douglas fir plywood.

Mr. John Bene (Western Plywood Co., Ltd.): Douglas fir is mainly used for structural purposes. For decorative purposes hardwood plywood panelling is used. The use of treated fir plywood (Weltex, Etchwood, etc.), as well as various species of decorative hardwood plywood, is subject to fashion trends.

Mr. J. H. Grant, Jr. (Burritt Lumber Sales Co., Inc.): What evidence is there that when building drops off, the industry will not prove to have been overbuilt?

Mr. Devlin: I don't believe the industry is overbuilt except possibly in terms of log supply. I believe this is borne out by prewar experience on industry growth and sales. Demand, by every statistical study, is still substantially ahead of capacity to produce. These studies are related to new housing starts, total new construction, population trends as well as general business conditions, area by area, throughout the United States. Demand, of course, influenced by constantly increasing price levels could reduce overall demand substantially. This has not occurred as yet.

Mr. E. R. Stivers (Package Research Laboratory): How does the yield of sliced veneer compare with that for rotary cut veneer?

Mr. Bene: Large sized high-quality logs can be converted into sliced veneers and subsequently into plywood yielding 40 to 50 percent plywood of the net log volume. In comparison, converting logs into plywood by rotary cutting yields in excess of 50 percent. Lower grade logs will often make good plywood economically when rotary cut, but are not suitable for slicing.

Hanrahan, Perkins, Locke, Hamilton.

Carter, Walters, Carr, Pauley, Chesley, Kaufert.

1950 ANNUAL BUSINESS MEETING

The meeting, held in the Rose Bowl of the Multnomah Hotel, Portland, Oregon, was called to order by President Locke at 1:00 p. m., Tuesday, June 27, 1950.

1. Minutes of Previous Meeting

Announcement was made that the minutes of the preceding annual business meeting, held in Grand Rapids, Michigan, on May 4, 1949, had been approved by the Executive Board and published in the Proceedings of the 1949 National Meeting.

2. Report of the Secretary-Treasurer

During the fiscal year 1949 the net paid-up membership decreased from 2014 to 1921. This does not include approximately 200 delinquent members, a large number of whom it may be assumed will resume active status, bring the total current membership to an increased figure over the preceding fiscal year.

While there was no formal membership drive during the period January 1–March 31, 1950, a comparison of the rate of acquisition may be had from the following: From April 1, 1948 through March 31, 1949 we enrolled 814 members. During the corresponding period for 1949–50 we enrolled 454 members.

An analysis of paid-up members shows 1737 voting and associate members, 101 supporting members and 184 student members. The Society now has members in 47 states, the District of Columbia, Hawaii, Alaska and Puerto Rico, all provinces of Canada and 24 foreign countries; Siam being the latest foreign country added to the roster during 1949.

The number of local sections has increased from 7 to 10 with the addition of the Lower Michigan, Upper Mississippi Valley and Deep South sections, all of which are active and have had at least one meeting. During the year, the Eastern Canadian section severed in order to form its own organization, the Canadian Institute of Forest Products.

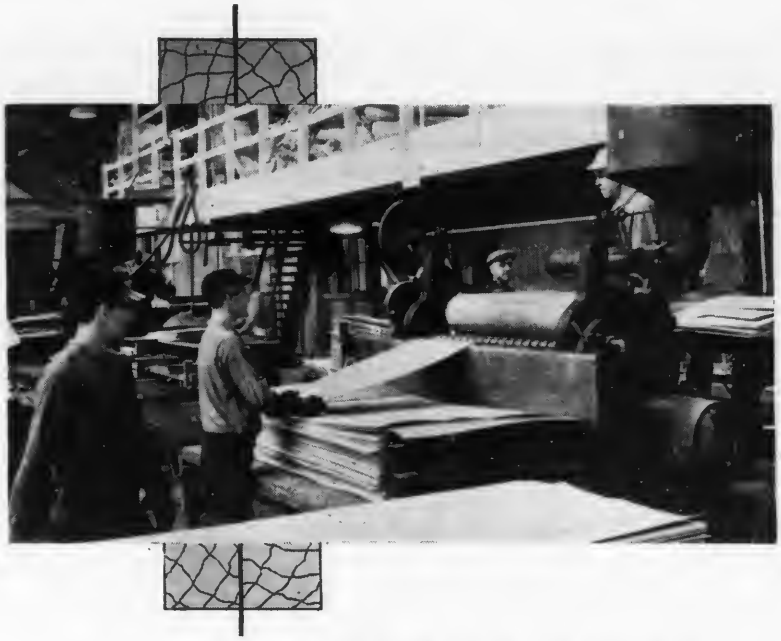
Cash on hand April 1, 1949, was $12,701.64. Total receipts during the fiscal year 1949 were $42,470.27. Expenditures were $40,207.86. Cash on hand at the end of the fiscal year (March 31, 1950) was $14,964.05. The Society's income was derived principally from membership dues, publications, advertising and meetings. The principal items of expense were for the operation of the central office, including salaries, stenographic service, communications, supplies, travel of executive officers and membership campaigns.

In addition to cash on hand, the Society has assets of $5,440 in accounts receivable and $1,171.86 in inventory (equipment, printed matter, and stamps). Also on hand, conservatively valued, are 1240 copies of Volume 1, 1286 copies of Volume 2, and 1340 copies of Volume 3 Annual Proceedings, plus a considerable quantity of reprints.

On motion duly made and seconded the report was accepted.

3. Auditor's Report

The auditor's report for the period from April 1, 1949, through March 31, 1950, was accepted by the Executive Board, and the Sec-



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retary-Treasurer instructed to print and distribute it to the members of the Society.

4. Section Activities

The President described his tour around the sections and reported all sections in a healthy condition. He attended the organization meetings of Lower Michigan and Deep South sections. Upper Mississippi is planning to meet this Fall. The petition for a new section, Pacific Southwest, will be reviewed during the current Executive Board meeting. Two sections, Northeast and Virginia–Carolinas, were commended for their efforts in publishing Section Proceedings.

5. Report of the Publications Committee

The Publications Committee was reorganized during the past year along the lines recommended in our report to the members at the Grand Rapids meeting. This reorganization has resulted in better functioning of the Committee.

Prior to the solicitation of papers for the 1950 meeting the Committee prepared a one-page set of recommendations to authors based on the Style Standards published in Volume 2 of our Proceedings. These recommendations were furnished all prospective authors by the Program Chairman. Although there was still some lack of conformance with these recommendations on the part of a few authors, they were felt to be very helpful and a decided improvement over the previous method of suggesting that authors consult the Style Standards. The Publications Committee recommends that the practice of sending prospective authors copies of the one-page set of "Suggestions to Authors" be continued in arranging the program for the 1951 meeting.

In the fall of 1949, the Executive Committee requested that the Publications Committee consider the question of a separate publication for the Forest Products Research Society. This matter was widely discussed with F.P.R.S. members by members of the Committee, and it was recommended that for the time being we continue with present arrangements. The desirability of a separate publication was recognized by all members but it was felt that until our membership was greatly increased and we were financially able to assume the cost of such a publication, it would be unwise to move ahead on this. However, it was recommended that the Executive Committee and the Publications Committee give the question of a separate publication consideration at future meetings.

The new procedure in handling papers for the Annual Meeting has worked out surprisingly well. Under the present system, papers go to the Madison office and are sent to Publications Committee members for review according to subject matter assignments previously agreed on. After review and preparation of recommendations by Committee members, papers were sent to the Chairman for consideration of comments, changes, and recommendations relative to acceptance, and then returned to the Madison office. Subject matter assignments to Committee members were as follows:

Logs, sawmills and lumbering—F. F. Wangaard
Shipping containers—R. C. Rietz
Pulp, pulpwood supply and wood particle boards—I. H. Isenberg
Quality control in forest products—E. A. Behr
Softwood plywood—J. B. Grantham
General interest—F. H. Kaufert

Papers were carefully reviewed and promptly handled by all Committee members. Compared to previous years, the work of reviewing papers was greatly simplified and speeded up through this procedure. The Chairman of your Committee would like to take this opportunity to commend all Committee members for their excellent handling of papers and the time they contributed to this end. Also, the Committee would like to express its appreciation to Mr. Donald Coleman, to other members of the staff of the Forest Products Laboratory, and to your Program Chairman, Mr. Hamilton, for their many contributions to the processing of the papers presented at this meeting.

PUBLICATIONS COMMITTEE
E. A. BEHR,
J. B. GRANTHAM,
I. H. ISENBERG,
R. C. RIETZ,
F. F. WANGAARD,
F. H. KAUFERT, *Chairman*

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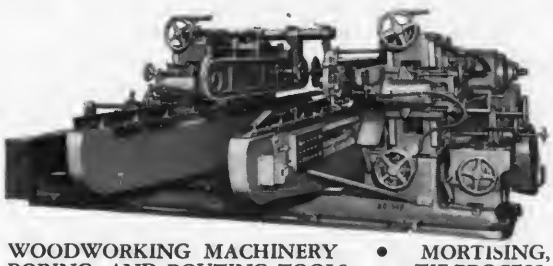

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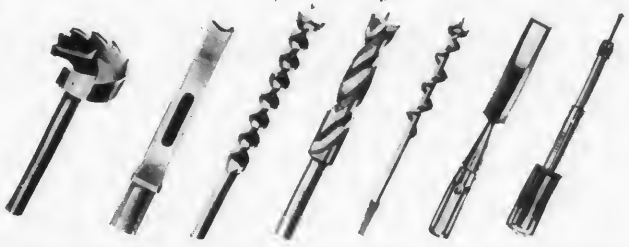

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6. Report of the Abstracting Committee

We have now made assignments to a total of thirteen abstractors. The list of those who have kindly volunteered to serve without fee as abstractors together with their assignments is as follows:

Mr. F. W. Guernsey, Wood (English)
Dr. E. S. Harrar, Quarterly Journal of Forestry
Mr. J. E. Lodewick, Timber of Canada
Professor A. J. Panshin, Lesochimicheskya Promishlenost, Lesnaya Promishlenost and General Assignment
Mr. N. V. Poletika, Russian General Assignment
Mr. G. J. Ritter, Australian Timber Journal
Mr. A. J. Snyder, Tappi, Paper Trade Journal
Mr. A. W. Stout, Timber News
Mr. L. C. Wallace, UNASYLVA
Professor F. F. Wangaard, Holztechnik vereinigt mit Sperrholand General Assignment
Dr. R. W. Wellwood, Revue Internationale du Bois
Dr. W. W. Varossieau, General Assignment
Mr. G. G. Marra, Canada Lumberman

In addition to these abstractors, who have received formal assignments, there have been recently added the following men who have special assignments as indicated:

Professor Bror L. Grondal, Miscellaneous foreign
Mr. Leonard Selbo, Norwegian

In addition, we have an additional group of volunteers for both English and certain foreign language publications who are prepared to add their efforts to this work:

Mr. Eskil Corneluissen
Mr. Melvin M. Madsen
Mr. A. V. Pedersen
Mr. R. H. Plow

All of the assignments that were originally authorized have been made, and it now appears in order to consider expansion of the assignments if additional funds are available. It must be remembered that in most cases we must be prepared to furnish the subscription as well as to bear the cost in the Secretary's Office connected with having the abstracts published. It is therefore recommended by the Abstracting Committee that we be told what expenditures may be made for the purpose of abstracting for the coming year and the cost of abstracting already underway so that we can determine the number of assignments that can be made additionally and get that work underway.

Respectfully submitted,
R. M. BROWN,
DR. IRVING H. ISENBERG
J. E. LODEWICK
G. J. RITTER
A. J. PANSHIN
C. B. HEMMING, *Chairman*

7. Report of Committee on Employment Service

The Committee was appointed in the fall of 1949, following action of the Executive Board of the Society.

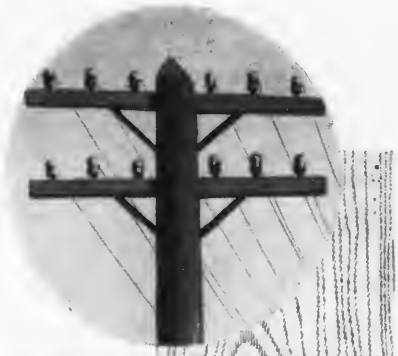
No specific functions were outlined but it was thought desirable to create a clearing house either through the secretary's office or at the national meetings or both, whereby prospective employees and employers might have information available or make contacts or both that might be beneficial to both parties and the Society.

Some correspondence has been handled by the office of the secretary and there is now on file with the Committee at this meeting, several letters from men desirous of making contacts with possible new employers.

The Committee will maintain an information desk at this meeting.

There is one point of policy that should be decided as it will cover the eligibility of persons receiving service. We are suggesting that the Committee be advised as to the preferable policy item from the following alternatives:

1. The service shall be available to only employers and prospective employees who are members of the Society.
2. The service shall be available to only employers and prospective employees who are members of the Society, except all recent college graduates will be considered regardless of membership.



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3. The service shall be made available to all employers who are members of the Society, but prospective employees need not be members.
4. The service shall be made available to any employer and prospective employee.

It is recommended that the permanent files be maintained in the office of the secretary and that the magazine "Wood" carry notices of the service.

As soon as expedient, a prepared statement relative to the service should be distributed among the membership and to the major accredited technical schools.

Respectfully submitted,
JAMES N. TYNAN
J. T. RYAN
GORDON D. LOGAN
IRA HATFIELD
PAUL M. DUNN, *Chairman*

8. Report of the Inter-Society Exploratory Committee

The report of this Committee was presented, in the absence of Chairman G. M. Hunt, by Frank J. Hanrahan, and is published with the papers of Technical Session V. On motion duly made and seconded the report was accepted with the appreciation of the Society extended to all Committee members for outstanding service to the Society and to the industry.

9. Report of the Resolutions Committee

Upon motion of the chairman of the Resolutions Committee, the following resolutions were adopted by the meeting:

(1) In recognition that the *success* of this Fourth Annual Meeting of the Forest Products Research Society is in a large measure due to the *foresight, planning* and *diligence* of the various responsible committees, and in particular of the Portland meeting committees,

Be it resolved that the Society hereby acknowledges its appreciation to the members of these committees for their excellent and successful work.

(2) In appreciation of the meritorious services that they have rendered to the Forest Products Research Society during their period in office.

Be it resolved that the gratitude of the Society be extended to all of our outgoing officers and Regional Board Members.

(3) The Society records with deep regret the passing during the last year of the following members:

Lambert Almquist
J. M. Bedford
Courtney Combs
F. S. Cutter
B. F. Faast
M. H. Hewett
L. V. Kline
W. J. Mallon
H. D. Marshall
F. X. Neuhaus
H. W. Nelson
H. S. Phillipson
H. H. Pittinger
J. D. Quist
E. A. Throckmorton
G. V. Treyz
B. F. Wade
C. L. Willis, and finally, our former secretary, T. R. C. Wilson

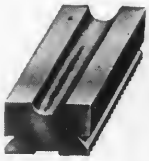
Be it resolved that this expression of sympathy to the families and friends of these men be included in the permanent records of this meeting and of the Society.

(4) In view of the splendid cooperation and services provided by our host Hotel, the Multnomah, in helping to make this annual meeting a success,

Be it resolved that the appreciation of the Society be extended to the Management and to the entire staff and that a copy of this resolution be forwarded to the Hotel.

(5) In deep appreciation of the hospitality and courtesies extended by the City of Portland and the State of Oregon, and with due regard to the climate and weather enjoyed during the meetings,

Be it resolved that this expression of gratitude to Governor McKay and the Honorable Mayor Lee, and to their able and friendly emissaries, Senator Walsh and Commissioner Kenneth Cooper, be forwarded to each by the So-



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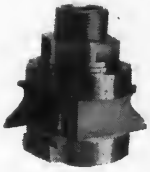

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ciety's Secretary, and also be entered on the permanent records of the Society.

RESOLUTIONS COMMITTEE
D. L. HAINES
FRANK HANRAHAN
RAY SHRECK
FRED H. VOGEL
N. S. PERKINS, *Chairman*

Upon motion duly made and seconded the preceding reports were accepted with grateful acknowledgments to the committee members for their efforts.

10. New Business

No new business was presented.

At this point President Locke acknowledged and thanked the various members of the regional and national nominating committees, and introduced the Chairman of the latter, Don Walters. Paying especial tribute to George Garratt and Carl Rishell, retiring members of the Board, and to R. D. Pauley and his entire Portland Meeting Committee, President Locke introduced each of the Board Members present.

A telegram, "Here's to the success of the FPRS Meeting" received from former President Fred Gottschalk was read to the assembly.

11. Report of the Tellers Committee

As the result of balloting for officers and board members for the Forest Products Research Society for 1950 the following were declared elected:

For *President:* James F. Hamilton, Ellicotville, New York.
For *First Vice-President:* Roy M. Carter, Raleigh, North Carolina.
For *Second Vice-President:* Kenneth G. Chesley, Crossett, Arkansas.
For *South-Central Regional Board Member* (3-year term): Moss B. Christian, Tallulah, Louisiana.
For *South-East Regional Board Member* (3-year term): Richard A. Hertzler, Asheville, North Carolina.

Attested by the Tellers Committee:
L. N. ERICSSON
HEREFORD GARLAND
ED LINN
R. W. WELLWOOD
R. N. HAMMOND, *Chairman*

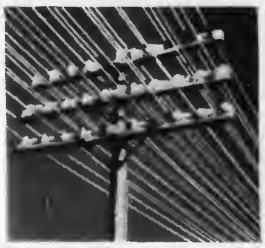
12. Installation of Officers

Newly-elected President Hamilton expressed his appreciation to retiring president Locke, retiring board members Garratt and Rishell and to the entire Board for their outstanding efforts in the past year. He thanked the assembly and membership for their confidence in their new leaders and expressed the hopes that all would continue to spread the principles of the Society, build membership and attend the 1951 Annual Meeting and Industry Show to be held at Philadelphia, May 7–11, 1951.

13. Adjournment

The meeting was adjourned at 1:45 p. m.

WHEREVER YOU USE WOOD..

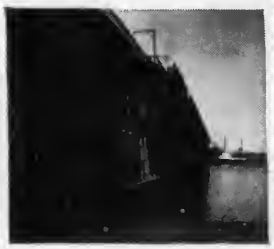


In the north, poles must resist the tremendous weight of frequent sleet storms. Barrett* Coal-Tar Creosote allows poles to retain their maximum strength, helps to keep the poles at their best.

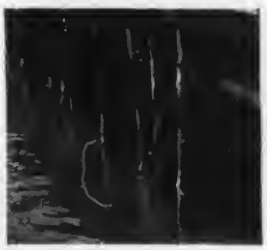
In the south, high temperatures cause light-bodied preservatives to leach and evaporate from the wood rapidly. Barrett Coal-Tar Creosote, heavier bodied and of lower volatility, prevents this condition.

In the desert, crossties broom, shatter and split from extreme dryness and heat. Solutions made with Barrett Coal-Tar Creosote retard this, and reduce wear of crossties through their lubricating action on the wood fibers.

In the swamps, high moisture content and infection from other decaying wood are menaces. Poles properly treated with Barrett Coal-Tar Creosote survive under swamp conditions for years.



In fresh water, many preservatives leach out of wood. Coal-Tar Creosote, being only negligibly soluble in water, is the preferred preservative for use on submerged wood structures.



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1950 FOREST PRODUCTS INDUSTRY SHOW

Registrants from all over the United States and Canada and many foreign countries, as well as logging and lumber men in the Pacific Northwest had an opportunity to view much of the latest in woodworking machinery, methods and materials at the 1950 Forest Products Industry Show.

The location of the Show was the city-block long Portland Armory in which fifty-six exhibitors filled eighty-eight booths, to near-capacity. The final *registered* attendance at the Show, to which admission was by invitation, was almost 900, most of them production and technical persons. Products displayed included logging, lumbering, high-frequency heating, materials handling, wood-working machinery, kilns, and other major equipment. In addition, a range of chemicals, preservatives, adhesives, and instruments were exhibited. Services were offered by associations, consultants, educational and research institutions.

A number of the machines were exhibited in actual operation enabling visitors to see production results. The Show was open from 10:00 a. m. to 10:00 p. m., and shuttle bus service operated each half-hour between the headquarters hotel and Armory.

Companies that placed exhibits in the 1950 Forest Products Industry Show included:

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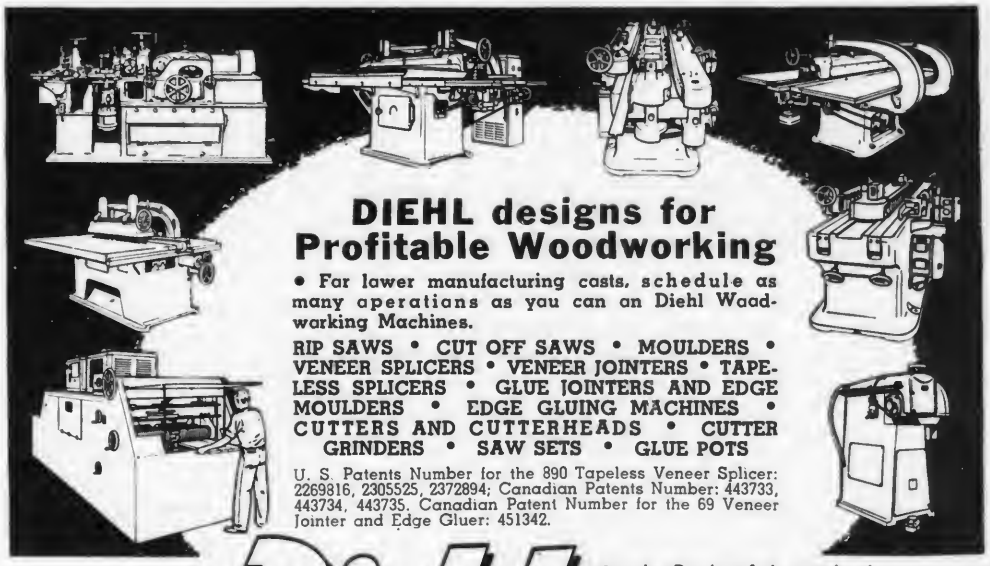

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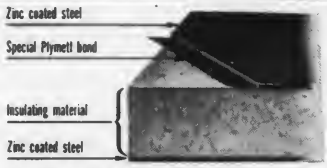

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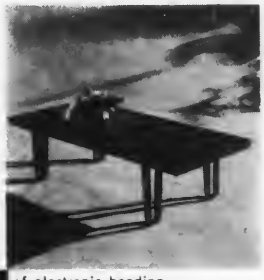

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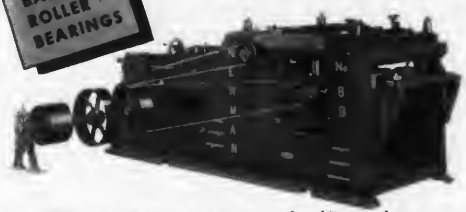

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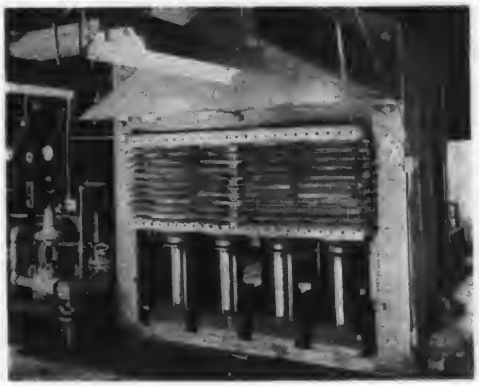

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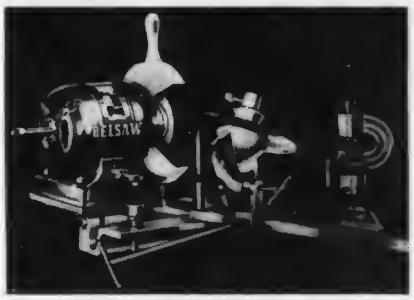

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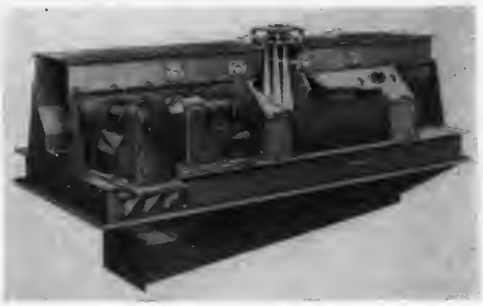

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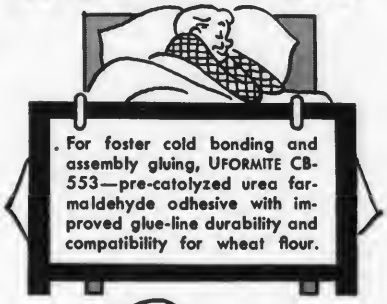

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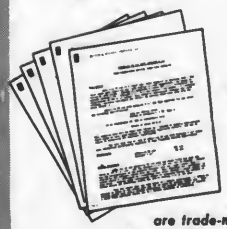

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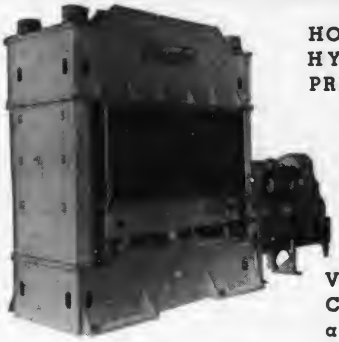

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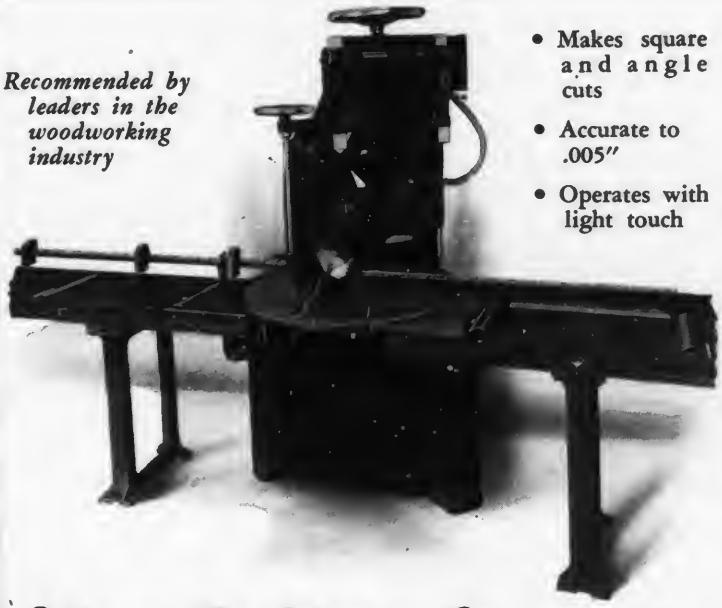

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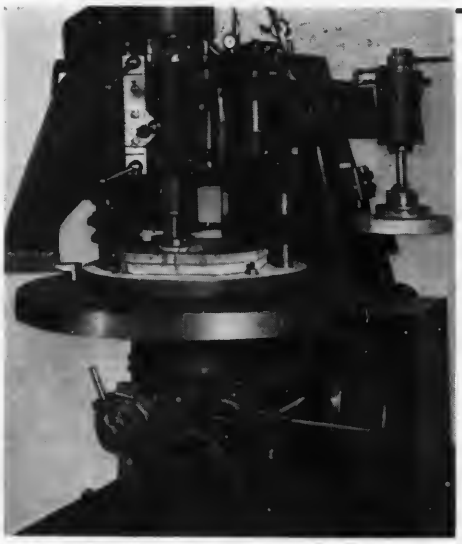

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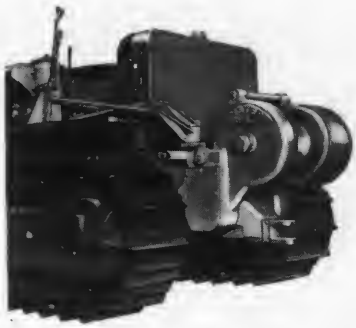

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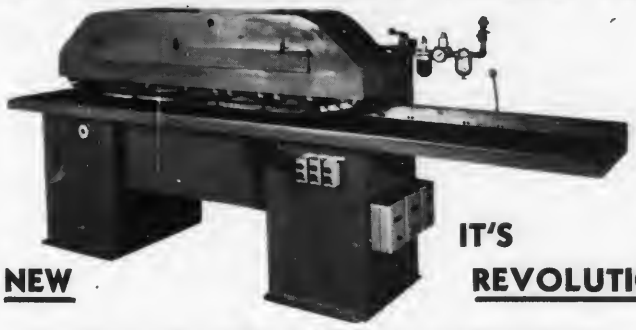

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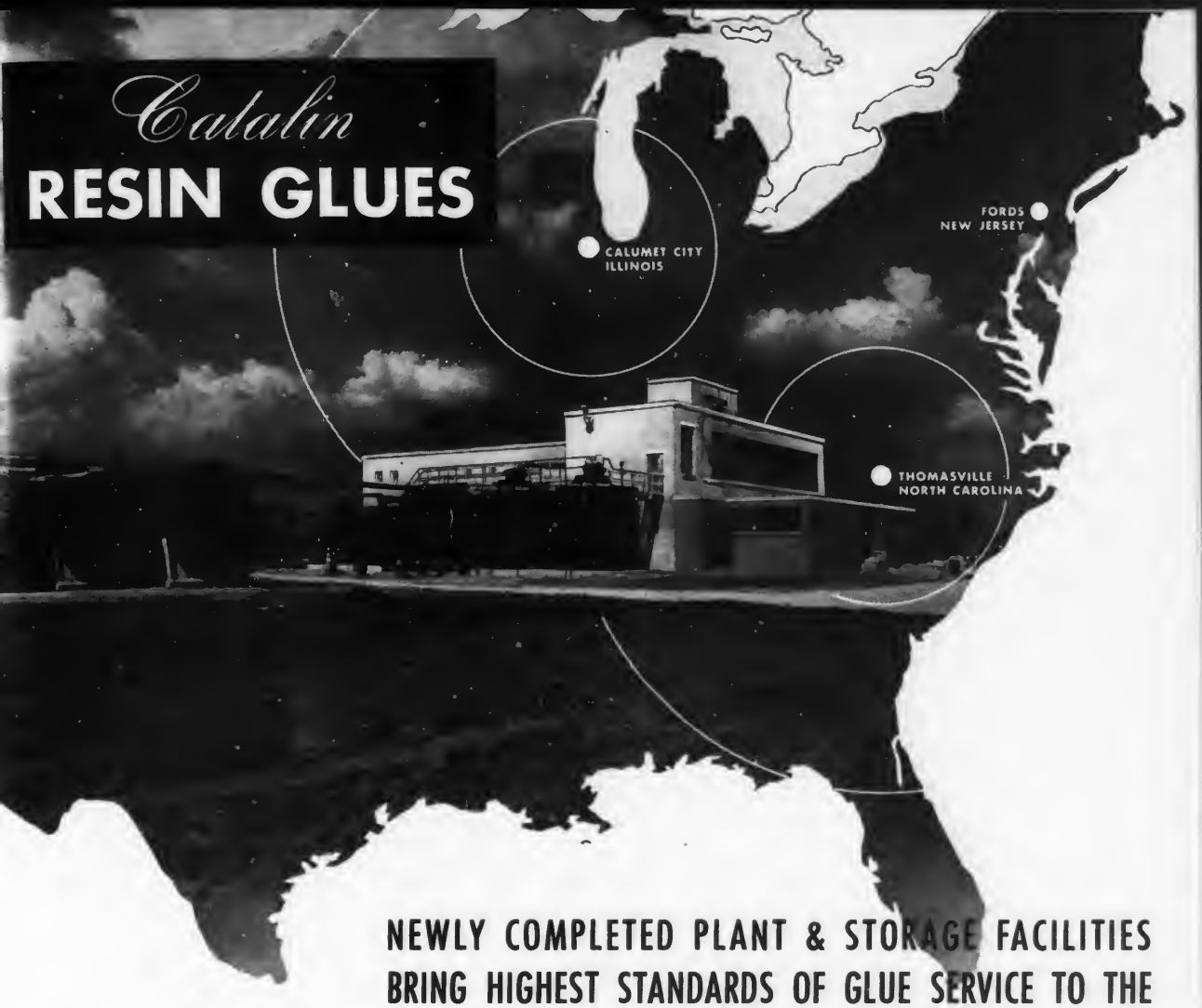

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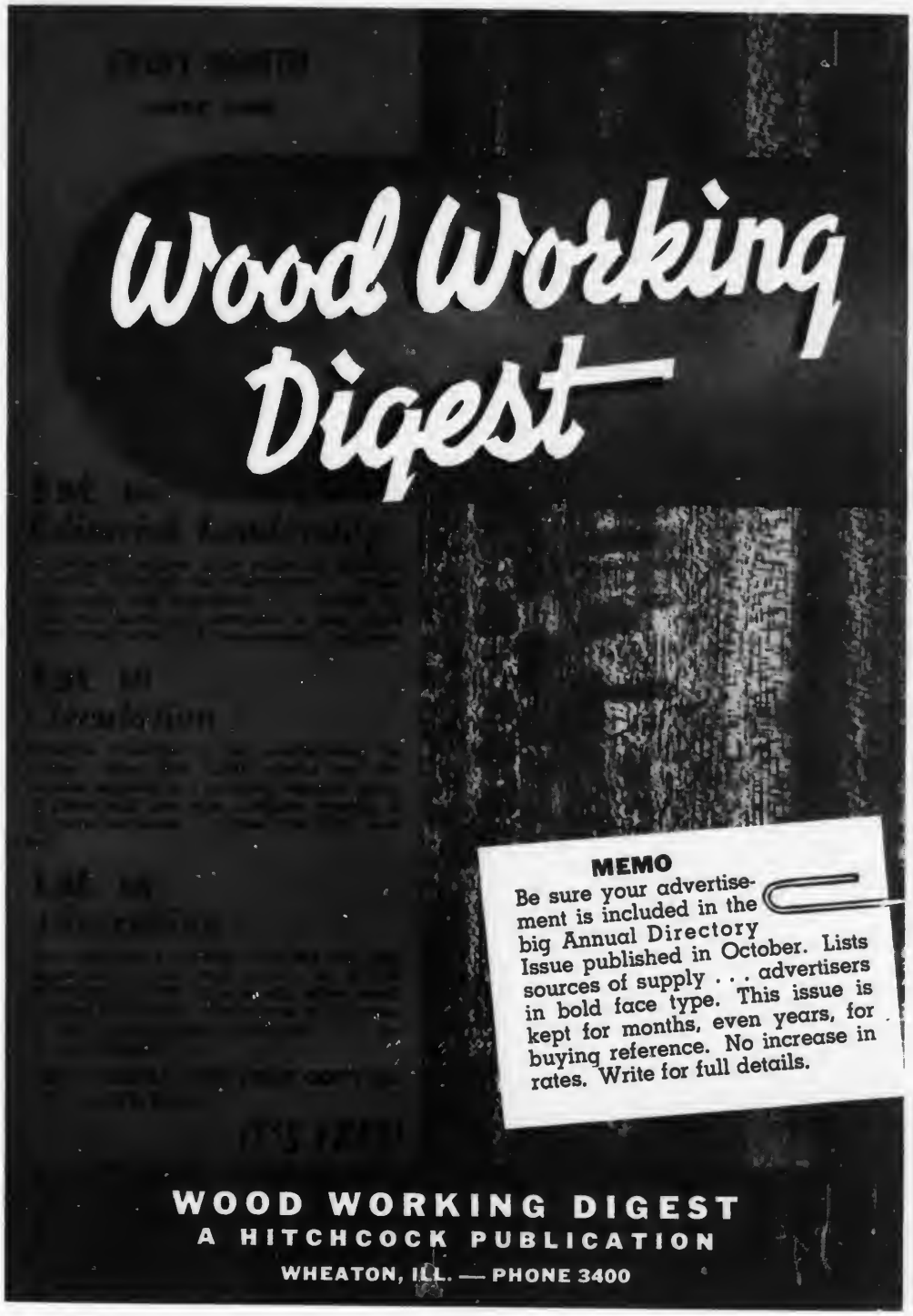
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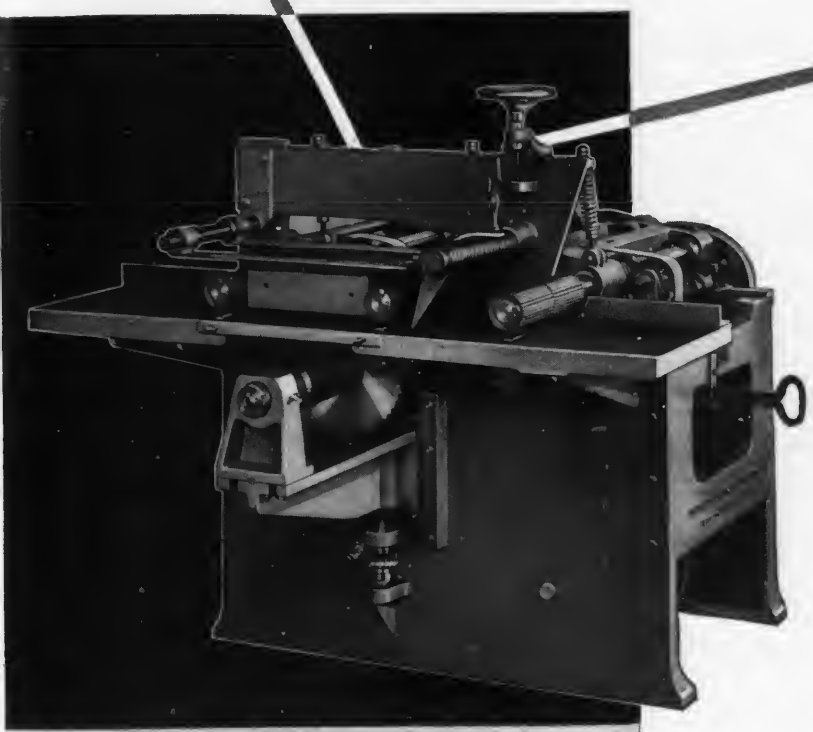

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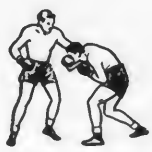

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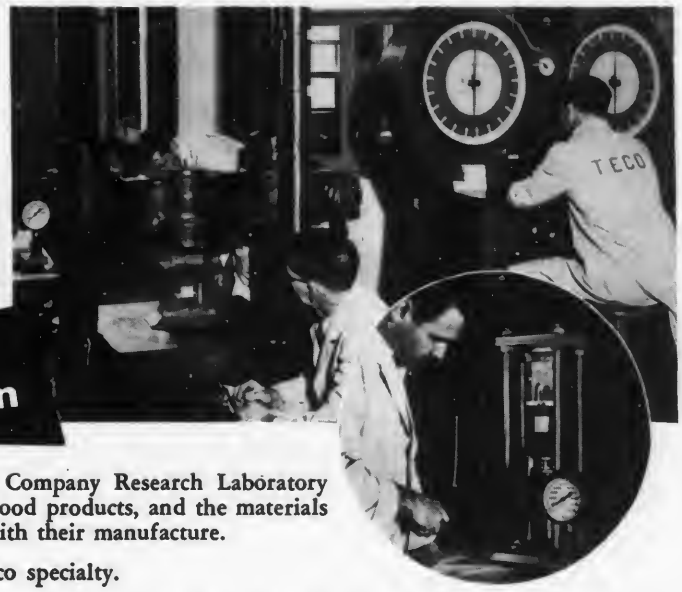

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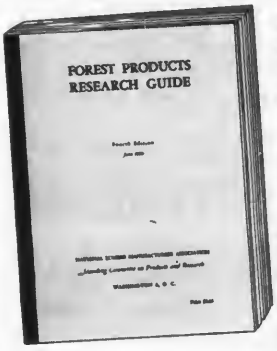

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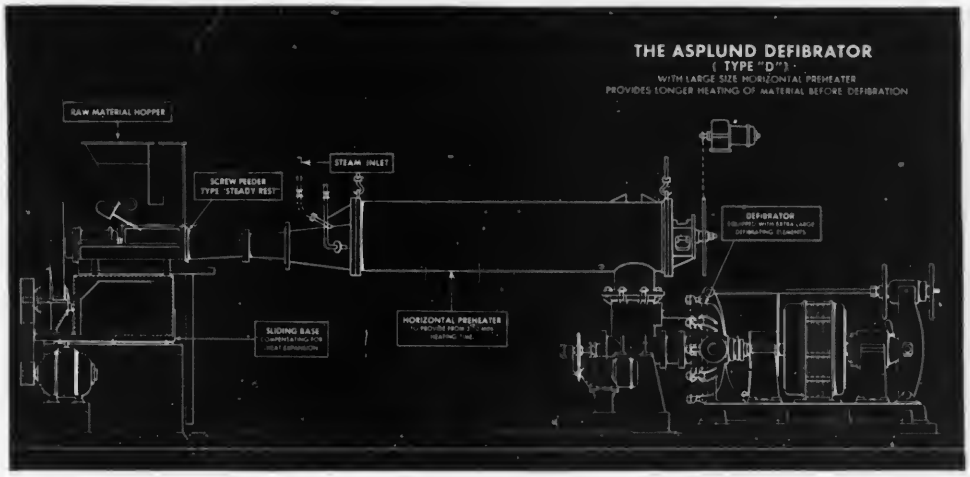

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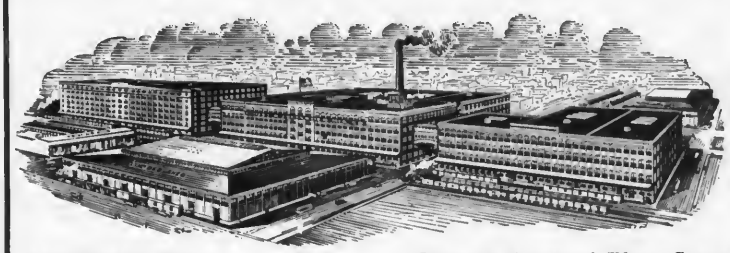

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Abel, John Stewart, Tacoma 1, Washington 2763v
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Allen, Armin E., Philadelphia, Pennsylvania 506v
Allen, George, Fortuna, California 1970v
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Anderson, Nils, Jr., New York 17, New York 1535v
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Anderson, Richard C., New Haven, Connecticut 2751as
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B

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Lyon, Allen A., Seattle 2, Washington 1769a
Lyons, William A., Oklahoma City 1, Oklahoma 723v

M

Mabesa, Calixto, Laguna, Philippines 903v
Mabrey, George R., New York 17, New York 1234v
Mabry, D. B., St. Louis 2, Missouri 546v
MacAdam, W. C., Lawrence, Massachusetts 2332v
MacDonald, G. B., Ames, Iowa 1492v
MacDonald, H. G., Monrovia, California 1352v
MacDonald, J. G., Vancouver, British Columbia 2037a
Macdonald, Mortimer D., Corvallis, Oregon 824v
MacGregor, R. Bruce, Macon, Georgia 2848v
Mackenzie, Donald W., Corvallis, Oregon 2819as
Mackerer, A. W., Algonac, Michigan 355v
Mackintosh, Charles, Los Angeles 4, California 2736v
MacLagen, C. F., Bainbridge, New York 1548v
MacLean, Angus D., Louisville 9, Kentucky 2686v
MacMillan Industries, Ltd., Vancouver, British Columbia 1599s
MacNair, C. S., Chicago 8, Illinois 2665v
Maddigan, S. E., Vancouver, British Columbia 1936v
Madsen, Melvin M., Bonner, Montana 1796v
Madson, Glenwood L., Pondosa, Washington 1934a
Magdsick, C. D., Pittsburgh 30, Pennsylvania 468v
Maheu, Claude F., Paris, France 1593v
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Maine, Albert B., Charlotte 7, North Carolina 1712v
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Malmstrom, H., Experimentalfaltet, Sweden 997a
Mangan, John W., Adair Village, Oregon 2049as
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Manson, B. C., San Francisco 4, California 1482s
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Marckworth, Gordon D., Seattle, Washington 11v
Marianelli, Luigi, Chicago 2, Illinois 1309v
Markwardt, L. J., Madison 5, Wisconsin 12v
Marlin, Clifton B., Durham, North Carolina 2084as
Marra, Alan A., Ann Arbor, Michigan 587v
Marra, G. G., Morgantown, West Virginia 58v
Marschke, Carl, Rib Lake, Wisconsin 1630a
Marsh, A. Fletcher, Chicago 4, Illinois 59v
Marshall, E. D., Lufkin, Texas 1123v
Marshall, H. Borden, Toronto, Ontario 318v
Marshall, Virl D., Corunna, Michigan 1938v
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Martin, C. Frederick, Nazareth, Pennsylvania 709v
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Mason, E. L., Kingsville, Texas 508v
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Matheson, Paul, Bingham, Maine 2128v
Mattison, Arthur M., Rockford, Illinois 2221v
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Mattson, W. C., Prospect, Oregon 1385a
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Merritt, Harry C., Downington, Pennsylvania 1381s
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Mest, John M., Harrisburg, Pennsylvania 2598as
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Miles, Thomas R., Beaverton, Oregon 395v
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Millar, J. Burton, Neenah, Wisconsin 237v
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Miller, Earl L., San Francisco 4, California 1633v
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Miller, Huguenin, Watervliet, Michigan 294v
Miller, J. Axel, DeKalb, Illinois 2300v
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Miller, Paul, Minden, Louisiana 678v
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Miller, William D., Raleigh, North Carolina 1721v
Millett, Merrill A., Madison 5, Wisconsin 2500v
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Mims, Lawrence W., Gainesville, Florida 610v
Minich, Arthur, Elizabeth F, New Jersey 335v
Minskey, S. V., Sr., Knoxville 2, Tennessee 190v
Mitchell, A. E., Marion, South Carolina 1592a
Mitchell, James M., Thomaston, Maine 2245v
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Mitchell, Leonard O., Forest Park, Illinois 1209v
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Moffitt, Wm. R., Seattle 8, Washington 343v
Moltesen, Peter, Copenhagen V, Denmark 2713v
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Monsanto Chemical Co., St. Louis 4, Missouri 552s
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Moore, M. W., Chatanooga, Tennessee 1004v
Moore, Raymond A., Morgantown, West Virginia 2840as
Moore, Robert C., Grand Rapids, Michigan 2205as
Moores, W. M., Rockport, California 1951v
Morath, Edgar, Washington, District of Columbia 2609v
Moreland, Donald E., Raleigh, North Carolina 2110as
Morgan, Robert K., Black Mountain, North Carolina 1072a
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Morm, Walter R., Pittsfield, Massachusetts 2669as
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Moyer, W. W., Camas, Washington 2572v
Mraz, Edward A., Madison 4, Wisconsin 2125v
Muehlman, Paul A., Philadelphia 40, Pennsylvania 979v
Mueller, Lincoln A., Missoula, Montana 1999v
Muhm, Robert E., Ames, Iowa 2485as

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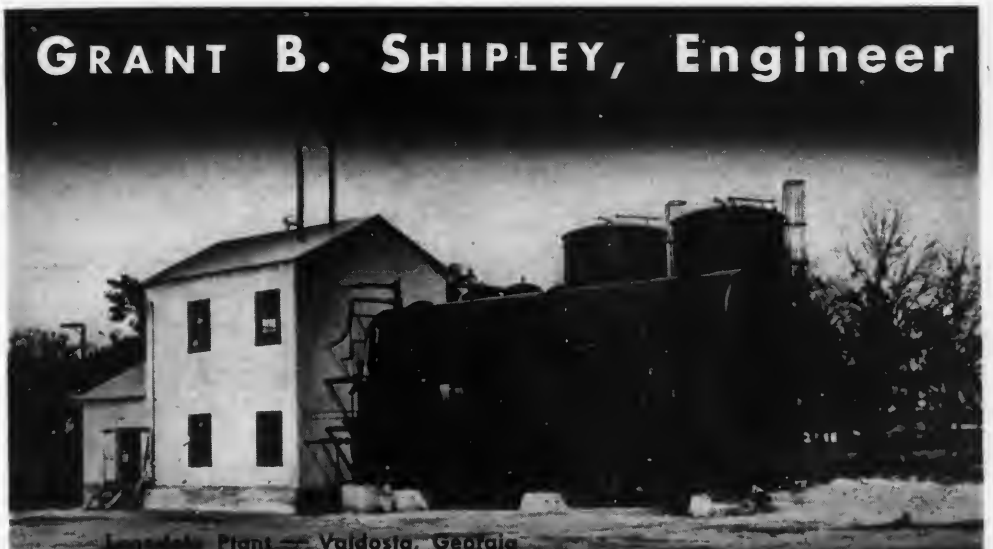

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Newell, H. V., Evanston, Illinois 1580v
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Nichols, Charles R., Jr., Jersey City 2, New Jersey 1227v
Nichols, Don E., Valdosta, Georgia 2536v
Nicholson, Fred, Seattle 4, Washington 1552a
Nickey, S. M., Jr., Memphis 12, Tennessee 1632v
Nissen, Donn Edward, Seattle 7, Washington 2515as
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Nolan, Clifford J., Jr., Shaker Heights 22, Ohio 2705as
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Norman, Wayne A., Dubuque, Iowa 295v
Norment, R. E., Lenoir, North Carolina 2224a
Norment, Richard E., Jr., Lenoir, North Carolina 1719as
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Northcott, Philip L., Vancouver, British Columbia 1538a
Northwest Furniture Mfrs. Assn., Seattle 1, Washington 1574s
Norton, Arthur J., Seattle 4, Washington 832v
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Nye, Arthur R., Grand Rapids, Michigan 2227as
Nyquist, Bernhard B., Rockford, Illinois 2283v
Nystrom, Leonard, Eugene, Oregon 1868v

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Oberg, William, Grand Rapids 9, Michigan 2624v
O'Brien, Alfred J., Chester, California 1949as
O'Brien, Edward H., Schenectady, New York 1143v
O'Day, Thomas W., Lowell, Massachusetts 2042v
Oettmeier, W. M., Fargo, Georgia 2851v
Ogden, Ronald E., St. Peters, N.S.W. Australia 1120v
Ogland, Nils Jul, Ornskoldsvik, Sweden 1590v
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Oleyar, Edward G., Syracuse, New York 2527as
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Pugh, L. R., St. Maries, Idaho 924v
Putman, Richard J. P., Ft. Collins, Colorado 2514as
Putney, Reid T., East Lansing, Michigan 2488as

Q

Quigley, R. I., High Point, North Carolina 2806v
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R

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Ranganathan, Shri C. R., Dehra Dun, India 1644v
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Rapp, Edward, New Haven, Connecticut 1270as
Rapp, George M., Raritan, New Jersey 836v
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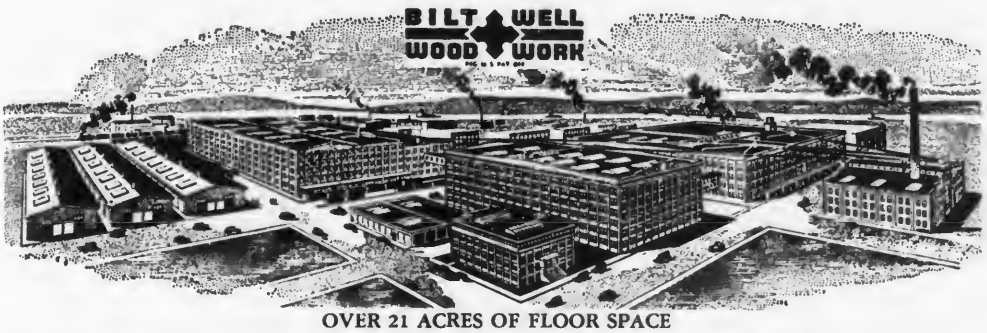

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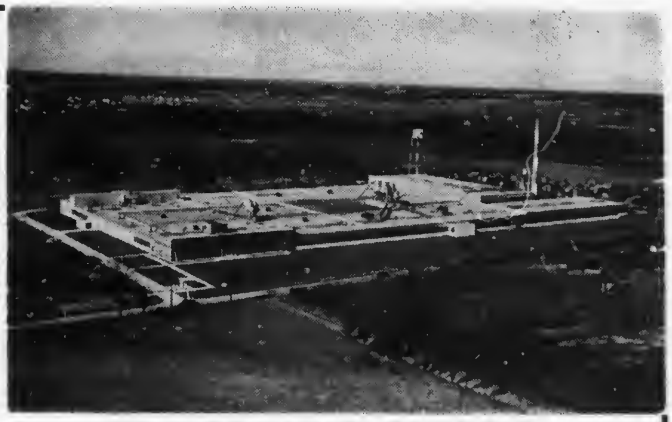

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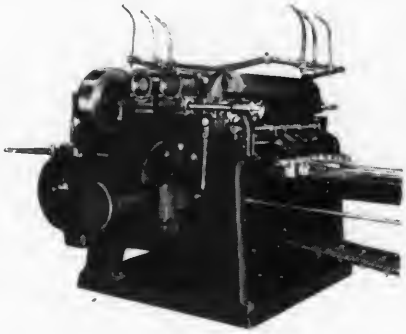

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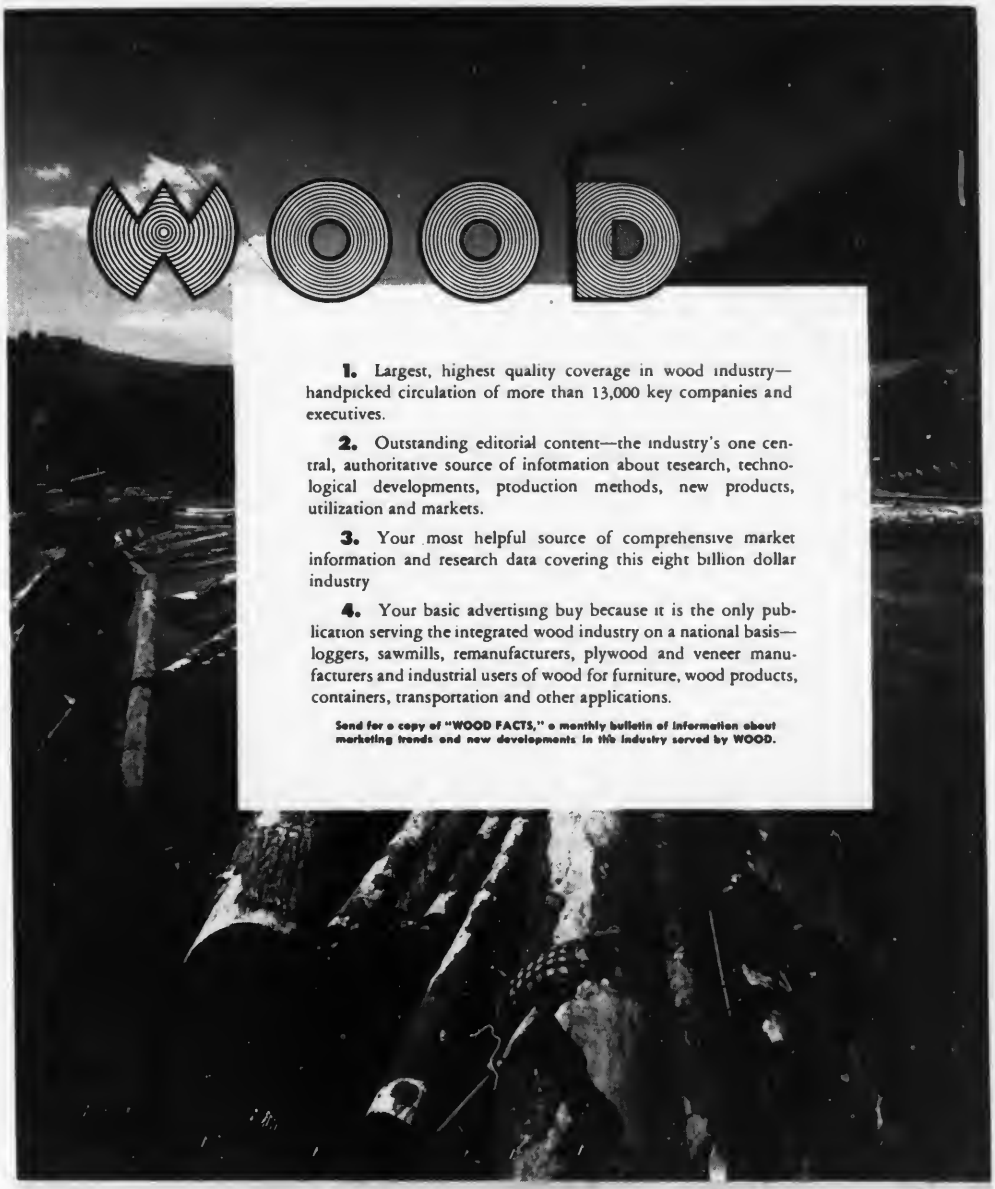
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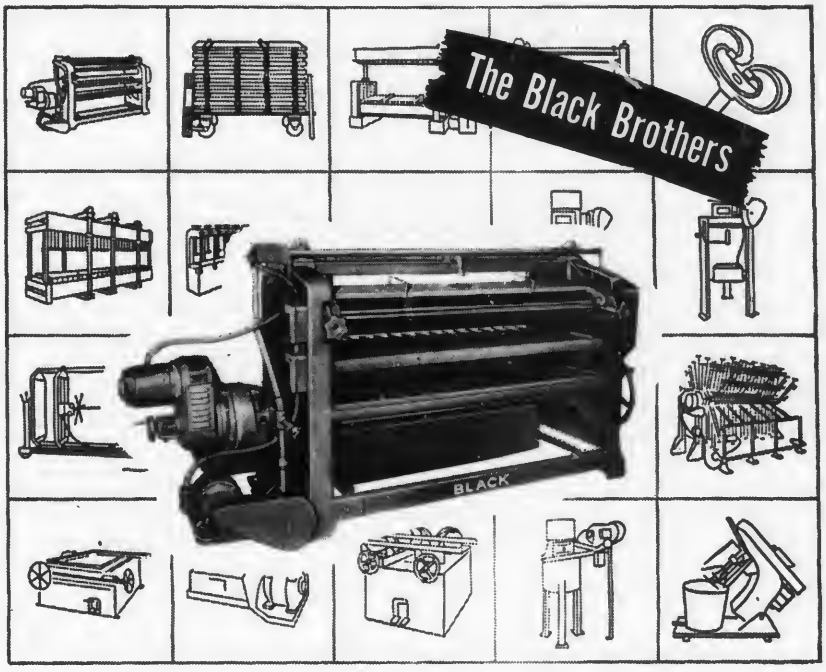

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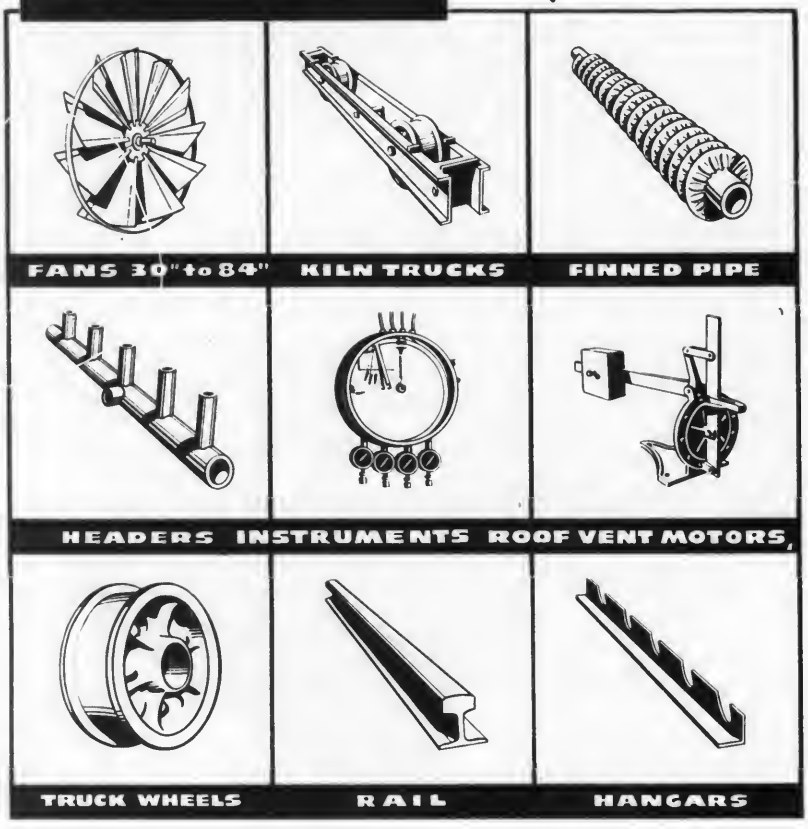

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